HUMAN CADAVERIC STUDY ON THE BRANCHING PATTERN OF EXTERNAL CAROTID ARTERY

Dissertation submitted in partial fulfillment of the requirement

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CERTIFICATE

This is to certify that the dissertation entitled **"HUMAN CADAVERIC STUDY ON THE BRANCHING PATTERN OF EXTERNAL CAROTID ARTERY"** is a bonafide work done by **Dr.G.B.LAKSHMI GAYATHRI**, in the Institute of Anatomy, Madurai Medical College, Madurai, under my guidance and direct supervision submitted to the Tamil Nadu Dr. M.G.R Medical University in partial fulfillment of University regulation for M.D., (ANATOMY BRANCH) to be held in April 2018.

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CERTIFICATE

This is to certify that the dissertation entitled **"HUMAN CADAVERIC STUDY ON THE BRANCHING PATTERN OF EXTERNAL CAROTID ARTERY"** is a bonafide work done by **Dr. G.B.LAKSHMI GAYATHRI**, in the Institute of Anatomy, Madurai Medical College, Madurai submitted to the Tamil Nadu Dr. M.G.R Medical University in partial fulfillment of University regulation for M.D., (ANATOMY BRANCH) to be held in April 2018.

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DECLARATION

I, **Dr.G.B.LAKSHMI GAYATHRI** solemnly declare that the dissertation titled **"HUMAN CADAVERIC STUDY ON THE BRANCHING PATTERN OF EXTERNAL CAROTID ARTERY"** has been done by me at Institute of Anatomy, Madurai Medical College, Madurai. I also declare that this bonafide work or part of this work was not submitted by me or any other for any award, degree, diploma to any other university board either in India or abroad.

This is submitted to The Tamil Nadu Dr. M.G.R. Medical University, Chennai in partial fulfillment of the rules and regulations for the award M.D. Degree (ANATOMY BRANCH) to be held in April 2018.

Place: Madurai

Date: **Dr. G.B.LAKSHMI GAYATHRI**

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CONTENTS

INTRODUCTION

The word carotid is derived from the greek word ‘Kapwrides’, which means ‘to stupey’ or ‘to throttle[21]. Kapos also means heavy sleep, says Skinner[68].

The common carotid, internal carotid, and external carotid arteries provide the major source of blood to the head and neck region[72]. The common carotid arteries are the beginning of the carotid system.

In the carotid triangle, the superior part of each common carotid artery(CCA) divides into external and internal carotid arteries. The external carotid artery(ECA) begins lateral to the upper border of the lamina of thyroid cartilage, level with the intervertebral disc between the third and fourth cervical vertebrae. At its origin, it is in the carotid triangle and lies anteromedial to the internal carotid artery(ICA). It later becomes anterior, then lateral, to the internal carotid artery as it ascends. The internal carotid artery(ICA) gives no branches in the neck region[72].

The external carotid artery(ECA) has eight named branches distributed to the head and neck. The superior thyroid, lingual and facial arteries arise from its anterior surface, the occipital and posterior auricular arteries arise from its posterior surface and the ascending pharyngeal artery arises from its medial surface. The maxillary and superficial temporal arteries are its terminal branches within the parotid gland[25].

Variations: The bifurcation of common carotid artery can sometimes be at a higher level, or lower level, or at level of cricoid cartilage[25]. Although the common carotid artery usually has no branches, it may occasionally give rise to the vertebral, superior thyroid, superior laryngeal, ascending pharyngeal, inferior thyroid oroccipital arteries. The lingual & superior thyroid artery may arise as common trunk. Also lingual may share a common trunk with facial artery[72].

A thorough knowledge about the blood vessels and nerves of the head, neck and face regions is very helpful in various therapeutic and diagnostic procedures and in surgeries like – thyroidectomy, laryngectomy, faciomaxillary surgeries, tonsillectomy, glossectomy and other neck surgeries[63]. Hence the aim of this study is to know about the course, relations and branching pattern of external carotid artery.

The carotid bifurcation (CB) is an anatomically and surgically important landmark as it is involved in the evolvement of intravascular treatments, including embolization and chemoembolization for head and neck tumors.

The external carotid artery right after its origin, starts giving off its branches and the morphology of these branches are highly variable, as anatomic variations are common in this area. It has renewed interest in the anatomic variations of this area, as they became clinically important in

surgical management, chemoembolization, and large defects restoration during management of head and neck tumors[3].

The branches of the External carotid artery are key landmarks and their knowledge is necessary for successful surgery and to minimize postoperative complications in bloodless surgical field[61]. Also the common carotid artery shows high frequency of early bifurcation, high bifurcation, trifurcation, quadrifurcation and short common stem, and these variations may lead to inadvertent injury and cause confusion in interpretation of angiograms[53].

A possible solution to the problem of high carotid bifurcation is carotid artery stenting, instead of carotid endarterectomy, as stated in most recent American Heart Association guidelines for stroke prevention[3]. The presence of a high common carotid artery bifurcation should caution surgeons that the hypoglossal nerve lies in closer proximity which is more vulnerable for injury[61].

The transposition of the External and Internal carotid artery and presence of a linguofacial trunk could have profound surgical implications and limiting access to the internal carotid artery during carotid endarterectomy. It also poses difficulties in catheter insertion. In addition, the risk of bleeding during pharyngeal surgery is increased in which the Internal carotid artery is medially displaced, due to its anomalous course[34].

Knowledge of the anatomy and variations of superior thyroid artery is important for clinicians to avoid iatrogenic injuries and postoperative complications in various procedures such as radical neck dissection, thyroidectomy, reconstruction of aneurysm and intervention radiology. The distances of the branches of the external carotid artery from the carotid bifurcation, especially the superior thyroid artery, is important in carotid endarterectomy where clamping of a branch may result in ischemia of the structure, which it supplies[24].

The branching pattern of external carotid artery as common linguofacial trunk and rare variations like thyro-linguofacial trunk were also recorded in various studies[82]. Linguofacial trunk may cause difficulties during surgical procedures in the neck such as extraoral ligature of the lingual artery[75].

A high origin of facial artery may also cause problems during procedures like parotid surgeries[49]. The anomalous branching pattern of common linguofacial trunk increases the risk of Iatrogenic injury in superselective intra-arterial catheterization or microsurgical reconstruction for head and neck cancer, so it is important to recognize an anatomic variation like linguofacial trunk[74].

Application of the knowledge of the precise origin and anomalous course of the facial artery is required for construction of facial artery myocutaneous flap and its successful utilization[33].

New super-selective intra-arterial infusion via the lingual, facial, or maxillary artery promises to be a new strategy of choice for the treatment of oral cancers[29], where anatomical knowledge of variations in the branching pattern of external carotid artery becomes inevitable.

Ligating external carotid artery or its branches in cases of severe epistaxis, elevation of various cutaneous, myocutaneous flaps for plastic and reconstructive surgeries of the head, neck and face which depends on the external carotid artery necessitates its morphological knowledge[63].

In spite of all these surgical importance, there are not many studies on the origin, and branching pattern of the external carotid artery as a whole. Thereby, the present study was undertaken to know the anatomy of the external carotid artery, its branching pattern and the possible variations which may benefit the surgeons and radiologists during vascular diagnostic interventional procedures and surgeries.

AIM OF THE STUDY

- To study the level of origin of ECA (External Carotid artery).
- To study the relation of ECA with ICA (Internal carotid artery).
- To study the branching pattern and origin of each branch of the ECA.
- To document any variations in the origin of ECA and its branches.

REVIEW OF LITERATURE

Carotid vessel is termed the apoplectic or soporal artery in recognition of the common effect of compression of both carotids, as credited by Aristotle as an earliest source of his observation[44].

Andreas Vesalius[5], 1543, was the first to observe the systematic details of the human vascular system.

The first operations consisted of proximal and distal ligations in case of carotid aneurysms was performed by Cogwell[17], 1803.

The role of the variations in the vascular tree was explored by the anatomist RichardQuain[57], 1844. He found the Superior thyroid artery(STA) to arise from Common carotid artery,than from external carotid artery(ECA).

Matas[46] in 1914, discovered the technique of applying metal bands for proximal ligation of carotid artery in case of aneurysms.

Egas Moniz[50], 1927, in his classic work, set the stage for the radiographic evaluation of the carotid arteries in the living patient by angiographic techniques.

The first successful surgery of carotid endarterectomy was performed by Michael Debakey[20] in 1953.

The effectiveness of collateral channels from the external carotid artery to the internal carotid artery, was emphasized by Hutchinson[28], 1957.

The origin of STA from Common Carotid Artery (CCA) is not uncommon and its incidence was given as 45% by Hollinshead[25], 1958.

Teal et al[77], 1973, in their studies had reported that the Ascending pharyngeal artery (APA), arose from the proximal end of ECA in 19% of cases.

John E. Conolly[31], 1973, had suggested the endarterectomy of ECA, in cases of extracranial cerebrovascular occlusive diseases. He had operated 45 cases of endarterectomy of external carotid artery, in cases of stenosis of the latter in accompaniment with internal carotid occlusion.

Von Poisel[83], 1974, had mentioned the possibility of the lingual artery arising from the carotid artery bifurcation level.

Smith[70], 1978, noted the origin of superior thyroid artery from CCA, proximal to the carotid bifurcation. He reports the incidence of STA to originate from CCA, to be from 5 – 45%.

Smith and larsen[71], 1979, observed the position of Internal carotid artery in relation to ECA. In 50% of the cases, it was posterior and was posteromedial in 8% cases.

Huber[27], 1982, had mentioned the bifurcation of CCA to be, at C4 to C5 vertebral level in 48% of the cases. The bifurcation can also occur as high as C2 vertebral level.

Incidence of linguofacial trunk as given by Bergman[12],1988, from his studies was 10- 20%. According to him the thyrolingual trunk was a rare combination.

Trigaux[79], 1990, evaluated 200 arteries at angiography, and found the Internal carotidto lie posterolateral to External carotid artery in 48%, and posteromedial in 13% of the cases.

In his studies, Koneko et al[32], 1996, reported that Superior thyroid, Lingual(LA) and Facial(FA) arteries were found to originate directly from Common carotid artery, in his studies. Additionally he observed Occipital artery(OA) with its sternomastoid branch, to arise from CCA directly.

Lucev et al[41] (2000), in his study, with 40 common carotid arteries , noted high level of bifurcation of common carotid artery in 5 cases(12.5%) and low level of bifurcation in 5 cases(12.5%). Also in a case, anterolateral position of external carotid artery in relation to the internal carotid artery was also noted (2.5%). One case of low level of origin of lingual artery and 8 cases of linguofacial trunks (LFT) were also observed by him.

Anil[6](2000), presented a case report with the occipital and posterior auricular arteries, arising as a short common trunk, which later divided into separate branches.

Lemaire[40], 2001, observed thethyrolingual trunk(TLT) dividing into superior thyroidand lingual artery, which followed an unusual course towards

their respective organs. Knowledge of this anomaly is important in neck surgeries.

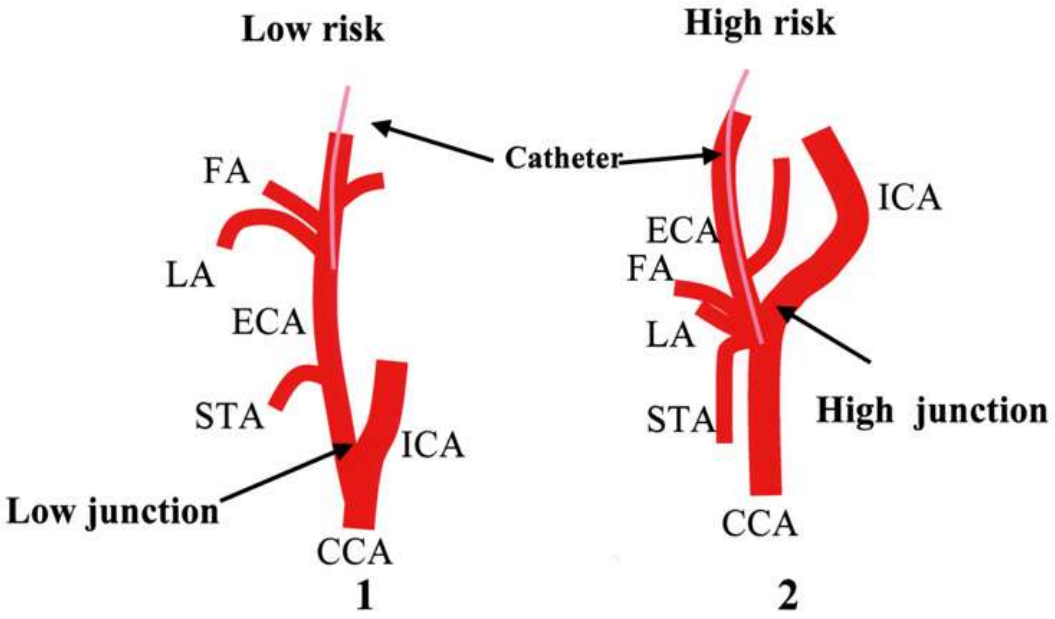
Marques[48], 2002, presented two caseswhich showed the occipital artery branching off very close to the carotid bifurcation, which characterized it as a trifurcation instead.

Hayashi et al[24] (2005), did his study by dissecting 98 carotid arteries. He observed, 30% cases of superior thyroid artery arising from common carotid arteries, linguofacial trunks in 18%, origin of occipital arteries above the level of facial artery in 57%. His study necessitated the need to understand the surgical anatomy of carotid arteries.

Zumre et al[84](2005), investigated 40 human fetus specimens, for carotid bifurcation levels and for variations in branches of external carotid arteries. He stated, 10% cases with C5 level bifurcation of CCA, 20% of linguofacial trunks, 2.5% of thyrolinguofacial trunk and 12.5% of occipito-auricular trunks.

Tony[78], 2006, says, an understanding of ECA anatomy is essential for interventional radiologists, since external carotid artery interventional studies isexclusively performed in the form of embolotherapy. In particular when one branch of ECA is small, then that area is supplied by an enlarged neighbouring branch, and these variations are important when endovascular therapy is considered.

Iwai tohnai[29], 2006, emphasizes that the conventional method of injecting an anticancer drug into a low lying artery such as lingual artery, ascertains the need to know the relation between External and Internal carotid arteries. In high bifurcation of CCA, the lingual artery and ICA, will be in close position, whereupon a linear catheter inserted to inject the anticancer drug, may get inserted into the ICA. When switching drugs in such cases will increase the risk of clotting in Internal carotid artery, leading to cerebral infarction.



Mahendrakar[43], 2007, during her routine cadaveric dissection, noted unilateral agenesis of lingual artery, hypoplastic facial artery and an enlarged transverse facialartery arising from external carotid artery. In this case, the hypoplastic facial component was compensated by the maxillary artery and transverse facial artery, that has originated from ECA. Also it was explained that, the lingual and facial artery territories would be recruited by ipsilateral

collateral pathways from STA. Such variations were due to deviation in annexation and regression of vessels during angiogenesis.

Bailey[11], 2007, identified 2 cadavers with lateral external carotid artery, on the right side. In both cases,the hypoglossal nerve passed lateral to the ECA. Bailey states that, in such cases, circumferential ECA dissection and medial mobilization is to be done, to preserve the hypoglossal nerve during ICA exposure in surgical procedures.

Anu[8], 2007, noted the bifurcation level of the common carotid artery, to be 50 percent at the C3 level, 40 percent at the C4 level, 10% percent at the C2 level, and one percent at the C5 level.

Zunon et al[85], 2008, investigated the collateral branches of the external carotid artery in about 60 cadavers, where he found 75% cases, having the origin of ECA at the level between hyoid bone and thyroid cartilage.

Chakravarthy[14], 2008, reported a case with bilateral variations of facial artery arising from ECA, above the greater cornu of hyoid bone. Also the right FA, did not make 'S' shaped loop in submandibular region. Such variations of facial artery paves the way for Doppler study prior to ipsilateral lip and cheek flap surgery.

Ozgur[54], 2008, in his study of carotid arteries with 20 cadavers, has calculated the micrometric values of carotid bifurcation, ECA and ICA. In

25% specimens, he observed the origin of STA below the Carotid bifurcation level.

Mohandas[60], 2009, has noted in a cadaver that STA was originating from CCA and superior laryngeal artery arising from ECA. Surgical procedures like emergency cricothyroidectomy, radical neck dissection etc, will have the risk of having postoperative complications, in such cases where one vessel is mistaken for the other.

Vazquez[80], 2009, conducted a study in 330 human neck specimens, where only the origin of STA was examined. The most common type of origin is from the level of CCA bifurcation(49%).

A case report by Mohandas[49], 2009, encountered to have the origin of Facial artery from ECA, about 2cm above the level of posterior belly of digastric muscle. Such variations is to be kept in mind during parotid surgeries.

A case was noticed by S Murono[51], in 2009, during the administration of intra-arterial chemotherapy for laryngeal cancer in a patient. It was an extremely rare case, where Carotid angiogram revealed a non bifurcating Common carotid artery on the right side. The ECA was absent on that side, with its branches arising from ICA, which was continuing from CCA. He had suggested that, embryologically the vascular bud for ECA had not formed and instead, the branches of ECA has gained theircontact directly with the third

aortic arch. In this case, later a superselective inta-arterial chemotherapy was performed.

Mamatha[45], 2010, reported an unilateral anomalous branching pattern of ECA, where the ECA has given a thyrolingual trunk and an auriculo-occipital trunk. These anatomic consequences may have important clinical implications.

Unique anatomic variations involving both right and left ECA were found by Thwin[76], 2010, says that in a cadaver, the variations were, high CCA on both sides with a linguofacial trunk and an occipito- auricular trunk on right side.

Virendra[81], 2010, observed the variations of carotid system in 30 cadavers, for a period of 3years. He noted a case with a thyrolingual trunk in a male cadaver.

Sanjeev[63], 2010, did a cross sectional study on the branching pattern of ECA. He found the STA to arise from CCA in 35.14% of cases. Only in 56.76% of cases, the anterior branches arose separately, while in others, as common trunks. The commonest trunk was between OA and ascending pharyngeal artery, and the least common to be thyrolingual trunk.

Al Rafiah[4], 2011, noted 5% of specimens having low bifurcation of CCA and 3.3% of specimens with high carotid bifurcation, when he dissected 30 cadavers. Thyrolingofacial trunk accounted for 1.7% cases.

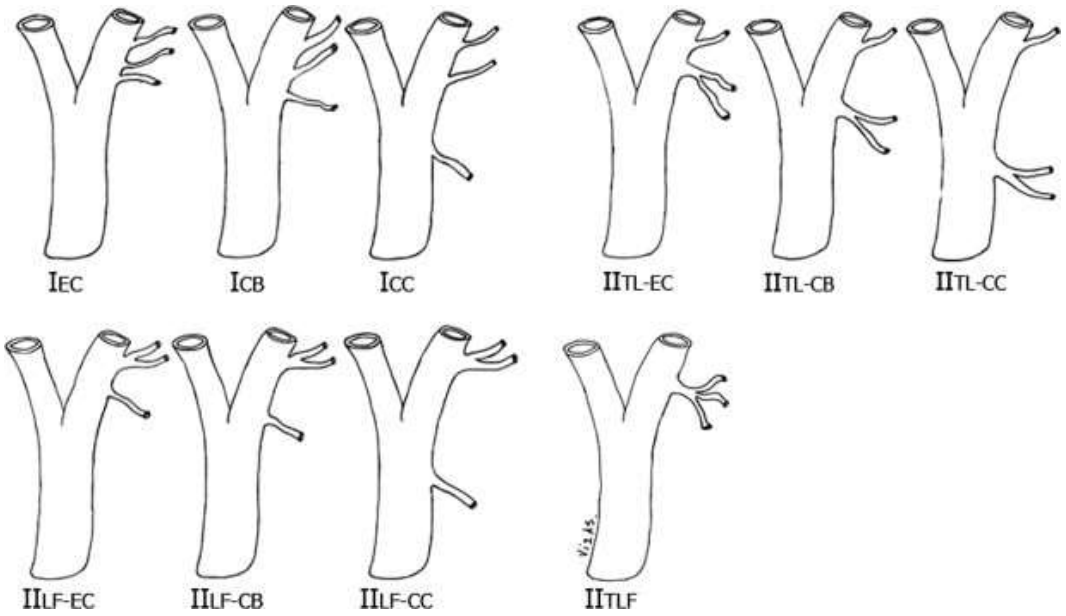
Prajakta[35], 2011, reported a case of high division of CCA i.e, above the level of greater cornu of hyoid bone, with linguofacial trunk, Superior thyroid, Occipital, Ascending pharyngeal, External carotid, and Internal carotid arteries, simultaneously arising from CCA on both the sides. The variation may be due to annexation and regression of vessels during development of ECA.

During routine dissection, Jadhav[30], 2011, reported a case of thyrolingual trunk arising from the bifurcation point of CCA. Awareness of this rare variation is essential during carotid and thyroid surgeries.

A rare variation of the lingual artery originating from the right CCA was reported in a male cadaver, by Surekha[75], 2011. This variation may be beneficial for ENT (Ear, Nose, Throat) surgeons and radiologists.

During dissection of a male cadaver, done by Ramesh[61], 2011, a rare variation in the branching pattern of ECA was observed. All the branches of ECA arose from the same point in ECA, just above its origin from CCA. This anatomic variation may have important clinical implications.

Konstantinos[36], 2011, had undertaken a study on the origin of superior thyroid artery, in 100 specimens from the Caucasian population. His classification proposal on the origin of STA, has stated the following figure given below;



EC – external carotid artery,

CB – carotid bifurcation,

CC – common carotid artery

TL – thyrolingual trunk,

LF – linguofacial trunk,

TLF – thyrolinguofacial trunk.

Sandeep[62], 2012, has reported a case of bilateral linguofacial trunk, during the routine dissection. This anatomic understanding of the facial and lingual artery is necessary for most of the cosmetic surgeries that takes place in the Head and Neck region.

Sujatha[73], 2012, has reported a rare anterolateral positional variation ofExternal carotid [ECA] artery in relation with the internal carotid artery [ICA]. It has been explained that, embryologically the external carotid arises

mainly from the ventral aorta and internal carotid arises mainly from the dorsal aorta.

Joao[47], 2012, studied the prevalence of the branches in the ECA, by dissecting 36 hemiheads of adult cadavers. He reported 19.9% cases of linguofacial trunk, 2.8% cases of thyrolingual trunk. He also observed STA arising from CCA in 3.5% cases. He says, linguofacial trunk was the most frequently observed variation.

A case report by Ramakrishna[59], 2012, was found to be unique ,in which he notified the presence of 'S' shaped tortuosity of Common carotid artery and , with the linguofacial trunk from the tortuous ECA. Such tortuosity of the arteries produces changes in the laminar flow, leading to strictures and stenosis.

Another case with the thyrolinguofacial trunk from left CCA, was reported in 2012 by Raju Sugavasi[58], during routine dissection. The knowledge of this variation is useful in carotid endarterectomy procedures.

Himabindu[26], 2012, in his study done in 20 cadavers, observed linguofacial trunk in 2 cadavers. In another cadaver, he noticed the ventral branches to arise from one point of external carotid artery. Surgeons doing reconstructive procedures of head and neckshould have these variations in mind to avoid iatrogenic injuries.

Madan[42], 2013, studied on thyrolingual trunks in 21 cadavers. He observed 2 cases of thyrolingual trunks to arise from CCA and both cases showed unilateral variation. Surgeons consider infrequently, of the ligation of

ECA, in case of haemorrhage which is either traumatic or operative. The usual surgical dictate, in ligating ECA, is to demonstrate the first branch of ECA (which is the Superior thyroid artery), and to ligate it above that branch. However, the disaster will fall upon the patient in presence of such anomalous thyrolingual trunk.

Gavrilidou[23], 2013, studied the morphological characteristics of the ECA in 80 human cadavers, representing a significant variability in thea) terminal carotid bifurcation,b) right – left asymmetry in termination of CCA, c) caliber of External carotid artery. The study makes its use for the radiologists during angiography.

In 2013, Dnyanesh's[74], case report stated unilateral linguofacial trunk from the ventral aspect of ECA, which helps the radiologists in interpreting the carotid system imaging.

Chan[15], 2013, has reported an aberrant superior thyroid artery arising from the right common carotid artery in a patient, who had underwent a successful carotid endarterectomy. It is always dangerous for surgeons performing the carotid endarterectomy, because the aberrant branch may be mistaken for the external carotid artery. Therefore, it highlights the awareness of the variations in these areas, to prevent the morbidity in surgeries.

Identification of arterial variation related to the thyroid gland is important in planning the surgical approaches to the thyroid gland. A study in

2014 by Abhijeet[1], done in 33 cadavers, denoted 1.51% cases, with STA originating from CCA. This knowledge about variations will alert the surgeons in thyroid resections.

Gangadhara[22], 2014, had presented a case ,with high origin of ECA from CCA. Most important was the presence of thyrolinguofacial trunk and the origin of superior laryngeal artery from ECA. Such a variation is helpful during reconstruction surgery of the larynx.

Anomalous origin of thyrolingual trunk was noticed in 3 specimens, during the study done in 33 cadavers in 2014**.** It is important for surgeons and radiologists to avoid complications during neck surgeries says Pulipati[55].

Shakuntala[66], 2014, noticed a very rare variation of trifurcation of external carotid artery. In this case, ECA terminated into superficial temporal artery, maxillary artery and also into, the middle meningeal artery. The probable explanation is, developmentally the ECA must have directly incorporated the supraorbital branch of the stapedial artery to form the stem of the middle meningeal artery.

A research done on the incidence of linguofacial trunk from external carotid artery, by Abhijeet[2], 2014, presented 15.38% specimens with unilateral linguofacial trunk and 3.8% specimens showing bilateral linguofacial trunk. Such common trunks will increase Iatrogenic risks in the tonsillar fossa.

Application of the knowledge of the origin and course of FA is required for FAMM (facial artery mucosal musculo-cutaneous) flap reconstruction. A case report of Laxman[39], 2014, stated the origin of FA to be high above the posterior belly of digastric muscle. Its unusual course may limit its use in FAMM flap reconstruction.

Vishnu[82], 2014, recorded the observations in his study with 30 cadavers. 3.3% variation with thyrolingofacial trunk and 11.3% with linguofacial trunks were found in his study which implied, the great variability of these arteries.

Khanal[33], 2015, reported a case with left Facial artery to have an abnormal course, originating in digastrics triangle, above the posterior belly of digastric muscle. One additional branch was found, branching from the anterior aspect of left ECA, between the site of origin of lingual artery and facial artery. This branch was looping upwards, and entering into the submandibular gland. Application of the knowledge of the precise course of facial artery is neccessory for facial reconstruction surgeries.

Puspalatha[56], 2015, conducted a study on the variations in the origin of Superior thyroid artery, in 50 cadavers. Three types of origins were noted.

a) From the external carotid artery in 68% cases

b) From common carotid artery in 24% cases

c) From carotid bifurcation in 8% cases.

Observations in the study by Ogengo[53], 2015, done in 224 heminecks, revealed the prevalence of conventional branching pattern of ECA,to be present in only 41.1%. Such wide differences, when compared to other studies may be due to ethnic variations embedded in heredity. 26.8% cases showed trifurcation of CCA, and 8.9% cases were with quadrifurcation of CCA. A frequency of 44.7% of linguofacial trunk, is relatively higher when compared to other studies.

Annette[34], 2015, has revealed the existence of a rare anatomic variant in a case. There was, transposition of ECA and ICA with the linguofacial trunk arising from the lateral ECA. It is expected to have difficulties in catheter insertion during procedures like carotid endarterectomy, in these cases.

In a 65 year male cadaver, there was a right ECA, which had terminated into MA and STA, at the level deep to the posterior belly of digastric muscle itself. Only the terminal branches of ECA has entered the parotid gland. This was observed by Surekha[75], 2015. This kind of variation causes iatrogenic injuries in maxillofacial surgeries.

Blanca[13], 2015, has reported 36.8% of cases with bifurcation of CCA to occur at the hyoid bone level. He explains the differences in bifurcation level in various subjects, to be the consequences of racial difference.

Variations in the caudal branches of the ECA, were studied in 79 cadavers by Heltzel[64], 2015. There was side dependent differences in the

origin of STA, i.e, mostly in the left side, the STA arose from CCA (57%). No other caudal branches showed the side differences. He suggests, the side variations of STA may be due to the difference in anatomy of CCA or may be due to the dynamics of the vascularisation of the two lobes of the thyroid gland following its descent.

Asha[10], 2016,has reported the incidence of linguofacial trunk to be 4%, in her study with 50 heminecks. Compared to previous studies, it is found to have less incidence.

Adamantinos[3], 2016, in his article, has stressed the importance of the micrometric values of carotid arteries and their branches with regard to their diameter, length and degree of tortuosity for understanding the disease and to design the surgical treatment, especially in cases of selection between carotid endarterectomy and carotid stenting.

In the cross sectional study of the variations of ECA, Anjalee[7], 2016, has reported the incidence of 28.33% of linguofacial trunks on the right side, whereas on the left side it was 30%. She has also observed the presence of 5% of occipito auricular trunk and the trifurcation of ECA in 1.67%. Incidence of linguofacial trunks was higher in her study.

Navakalyani[52], 2016, during her study on 60 dead fetuses found 8% of cases with linguofacial trunk and 2% of specimens with thyrolingual trunk.

Anuradha[9], 2017, has given 10% incidence of linguofacial trunk, in her study. In extraoral ligation of lingual artery during head and neck surgeries, these possible variations is to be kept in mind.

MATERIALS AND METHODS

The present study was conducted in Institute of Anatomy at Madurai Medical College, Madurai.

SOURCE

The present study was carried out in 50 hemi – necks obtained from formalin preserved human cadavers of Institute of Anatomy, Madurai Medical College.

INCLUSION CRITERIA

The cadavers belonging to different age groups and both the sexes available from the Institute of Anatomy, Madurai Medical College were included in the study.

EXCLUSION CRITERIA

The specimen's which were damaged during embalming, done through carotid artery was excluded. Cadavers having damaged carotid arterial system due to iatrogenic cause or due to any interventional procedures was excluded. The cadavers which has suffered from any neck injuries or any other gross abnormalities were also excluded.

STUDY DURATION

June 2015 – June 2018.

ETHICAL CLEARANCE

Obtained.

Fig. 1 INSTRUMENTS USED

INSTRUMENTS USED DURING DISSECTION

- Scalpel
- Toothed forceps
- Non – toothed forceps
- Scissors – small and large
- Cotton
- Gloves and Apron
- Digital camera

METHODOLOGY

Observation after dissection method

The external carotid artery and its branches were studied by gross dissection method, which involved the exposure of the artery **in the carotid triangle**, opening of the carotid sheath, tracing its origin, and its branches, after which piecemeal dissection of the parotid gland was done to expose its terminal branches.

Two incisions were made in the anterior aspect of the neck. First incision was made from the mental protuberance to the jugular notch. The second incision was made from the mental protuberance, which runs backwards and laterally through the body of the mandible, along its lower

border to its angle. The incision was extended from the angle of the mandible, backwards and upwards to the tip of the mastoid process[67].

The skin was then reflected infero-laterally from the front and sides of the neck. The superficial fascia containing the platysma with nerves and the deep fascia forming the roof of anterior triangle of the neck were all removed. The sternocleidomastoid muscle was cut in the middle and reflected supero-laterally. The anterior belly of digastric and the infrohyoid muscles were cut and reflected. The submandibular gland was pushed aside. The ansa cervicalis loop which was seen was sacrificed[67].

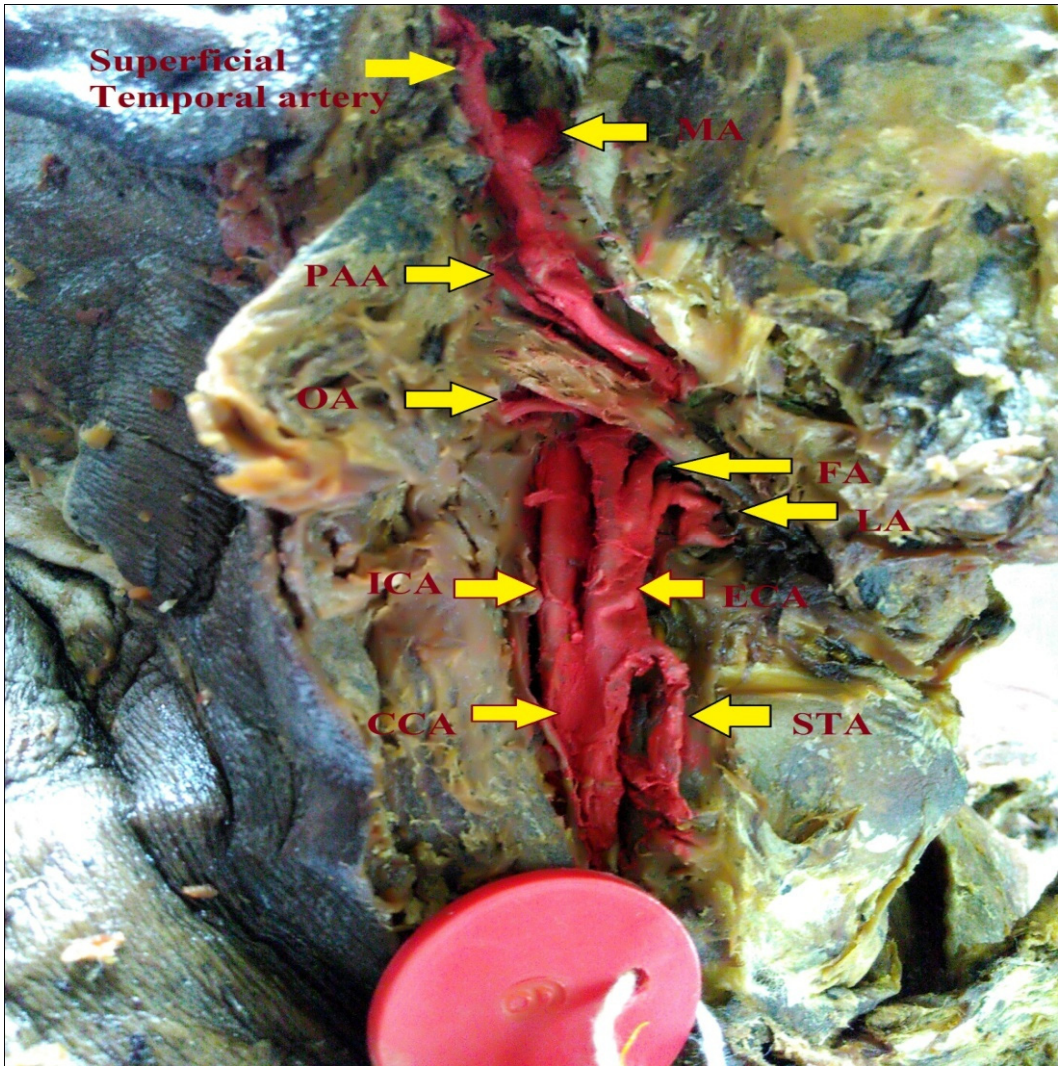
The contents of the carotid triangle were exposed by opening the carotid sheath. The carotid sheath was incised for exposing the carotid artery and its bifurcation. The carotid sheath is a fascial sheath which covers the internal jugular vein, internal carotid artery, the vagus nerve all around[18]. The external carotid artery lies outside the sheath.

The bifurcation of the common carotid artery level, into internal and external carotid artery was noted. The external carotid artery was traced upwards. Its relation to the internal carotid artery was noted. The branches of the external carotid artery were dissected and exposed. Traced from below upwards, they were the superior thyroid artery, ascending pharyngeal artery, lingual artery, facial artery, occipital artery, and the posterior auricular artery[18].

Still upwards, the deep cervical fascia covering the parotid gland was removed. The gland lies below the zygomatic arch, in front of the mastoid process, and behind the ramus of the mandible, which it overlaps. The substance of the gland is removedin piecemeal and the external carotid artery which ends by dividing into the superficial temporal and maxillary artery branches, at the level of the neck of the mandible was noted[18].

All the branches and course of external carotid artery were made visible, variations if any was noted down.

Fig. 2 NORMAL COURSE AND BRANCHING PATTERN OF EXTERNAL CAROTID ARTERY



CCA – Common carotid artery, ICA – Internal carotid artery

ECA – External carotid artery, STA – Superior thyroid artery

LA – Lingual artery, FA – Facial artery, OA – Occipital artery

PAA – Posterior auricular artery, MA – Maxillary artery

NORMAL ANATOMY OF EXTERNAL CAROTID ARTERY

The standard text book of Anatomy (Grays)[72], describes the course of external carotid artery and its branches as follows:

The common carotid, internal carotid, and external carotid arteries provide the major source of blood supply to the head and neck. On both the sides, as the common carotid artery ascends, it diverges laterally from behind the sternoclavicular joint, upto the level of the upper border of the lamina of thyroid cartilage of the larynx (C3-C4vertebral junction), where it divides into external and internal carotid arteries.

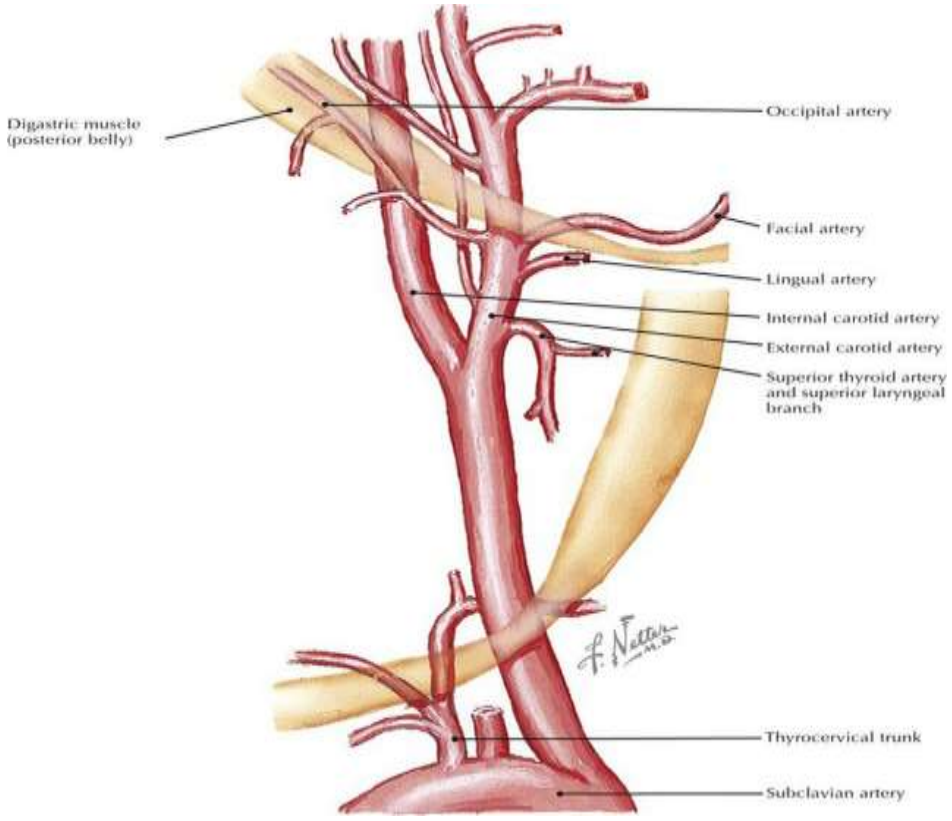
The external carotid artery begins lateral to the upper border of the lamina of the thyroid cartilage, level with the intervertebral disc between the third and fourth cervical vertebrae.

At its origin, it is in the carotid triangle and lies anteromedial to the internal carotid artery. It then becomes anterior and lateral, to the internal carotid artery as it ascends.

The external carotid artery has eight branches distributed to the head and neck region. The superior thyroid, lingual and facial arteries arise from its anterior surface, the occipital and posterior auricular arteries arise from its posterior surface and the ascending pharyngeal artery arises from its medial surface.

The maxillary and superficial temporal arteries are its terminal branches within the parotid gland.

RELATION OF POSTERIOR BELLY OF DIGASTRIC MUSCLE WITH THE BRANCHES OF EXTERNAL CAROTID ARTERY.



Superior thyroid artery

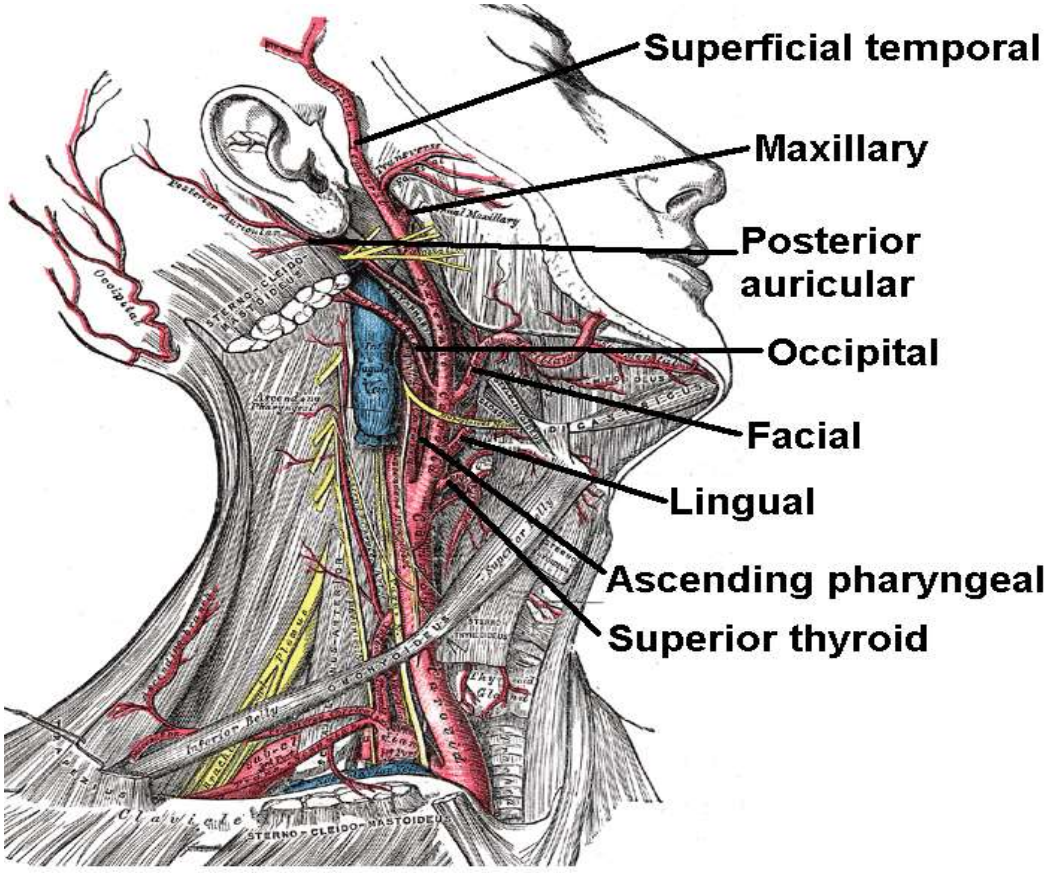
The superior thyroid artery being the first branch of the external carotid artery, arises from the anterior surface of the external carotid artery, just below the level of the greater cornu of the hyoid bone.

Ascending pharyngeal artery

The ascending pharyngeal artery is the smallest branch of the external carotid artery. It arises from the medial (deep) surface of the external carotid artery, near the origin of that artery.

Lingual artery

The lingual artery provides the chief blood supply to the tongue and the floor of the mouth. It arises from the external carotid artery opposite the tip of the greater cornu of the hyoid bone, between the superior thyroid and facial arteries, and below the posterior belly of digastric and stylohyoid muscle.



Facial artery

The facial artery arises anteriorly from the external carotid in the carotid triangle, above the lingual artery and immediately above the greater cornu of the hyoid bone, deep to the posterior belly of digastric and stylohyoid muscle.

Occipital artery

The occipital artery arises posteriorly from the external carotid artery, approximately 2 cm from its origin, opposite to the origin of facial artery, deep to the posterior belly of digastric and stylohyoid muscle.

Posterior auricular artery

The posterior auricular artery is a small vessel which branches posteriorly from the external carotid just above digastric and stylohyoid.

The maxillary and superficial temporal arteries are its terminal branches within the parotid gland.

DEVELOPMENT OF EXTERNAL CAROTID ARTERY

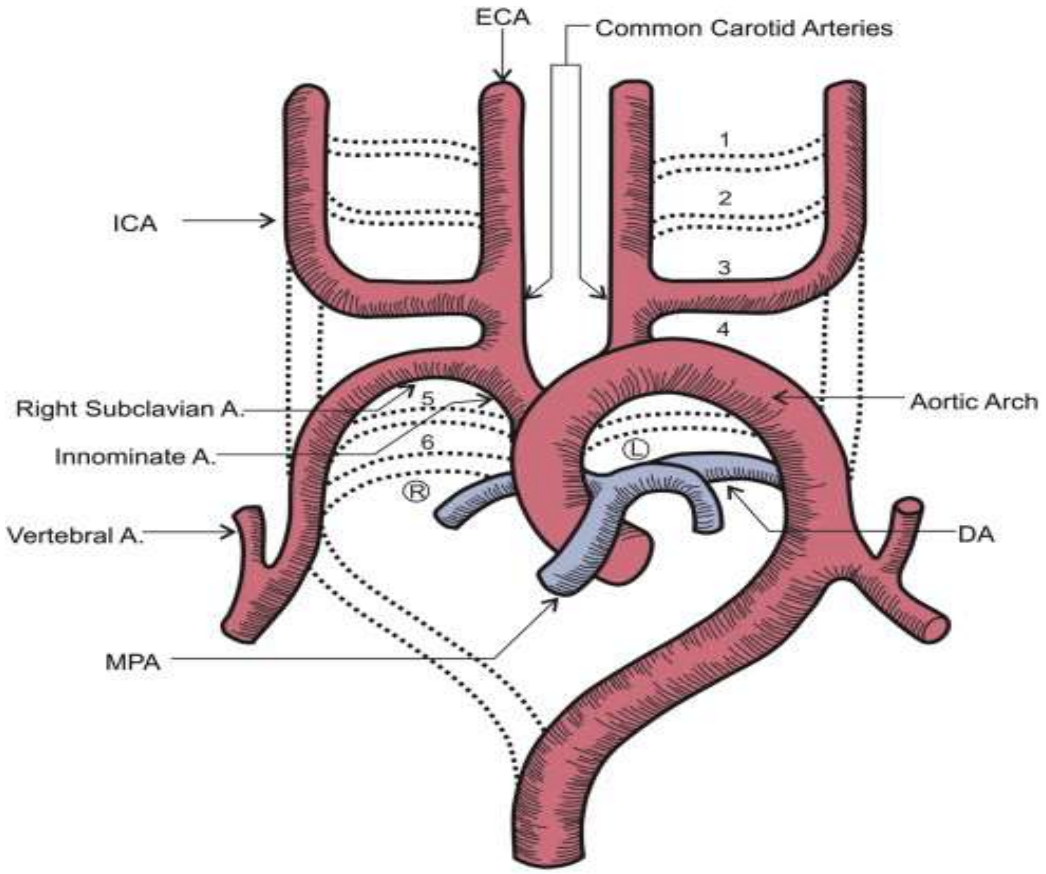
When pharyngeal arches develop during the fourth and fifth weeks, each of the arch receives its own cranial nerve and its own artery. These arteries are called the AORTIC ARCHES, which arise from the aortic sac, the most distal part of the truncus arteriosus. The aortic sac gives rise to total of five pairs of arteries i.e. I, II, III, IV, VI aortic arches(Vth arch will regress)[37].

On day 27, the first arch will disappear, even though a small portion of it forms the maxillary artery. Similarly the second aortic arch disappear, and the rest of the portions will form the hyoid and stapedial arteries[37]. By 35th day, segments of dorsal aorta connecting the third and fourth arch arteries disappear on both sides, thereby, the head receives its entire blood supply through the third aortic arch[38].

The third aortic arch gives rise to the common carotid artery, and the first part of the internal carotid artery. The rest of the internal carotid artery is formed from the cranial portion of the dorsal aorta. The external carotid artery (ECA) is developed as a sprout from the third aortic arch.

From this point of view, the internal carotid artery is considered as a continuation of the common carotid artery and the external carotid artery, as its branch. Origin of the ECA branches, interacts with development of the corresponding vascularized areas[37].

Rare cases of nonbifurcating carotid artery and the branches of External carotid artery originating from non-bifurcating carotid artery indicate the persistence of primitive hyoid-stapedial system, substituting the normal development in case of embryologic arrest. These variations can go unnoticed throughout life, as they may be asymptomatic. Different and largely unknown mechanisms including regression of vessels and common trunk for vessels have been proposed to explain anatomical variability in this area[3].



Embryology of Aortic Arches

ECA = External Carotid Artery
ICA = Internal Carotid Artery
MPA = Main Pulmonary Aorta Dividing Into Right (R) and Left (L) Pulmonary Arteries
DA = Ductus Arteriosus

OBSERVATION

After a thorough knowledge about the external carotid artery, its origin, course, branches and termination, this study was undertaken and the following parameters were observed.

PARAMETERS SEEN

1) Origin of **external carotid artery**.
2) Relation of **external carotid artery with internal carotid artery**, within the carotid triangle.
3) Origin of **superior thyroid artery.**
4) Origin of **ascending pharyngeal artery.**
5) Origin of **lingual artery.**
6) Origin of **facial artery.**
7) Origin of **occipital artery.**
8) Origin of **posterior auricular artery**
9) Termination of external carotid artery with
    a) Origin of **maxillary artery.**
    b) Origin of **superficial temporal artery**.

Fig. 3 NORMAL LEVEL OF BIFURCATION OF COMMON CAROTID ARTERY

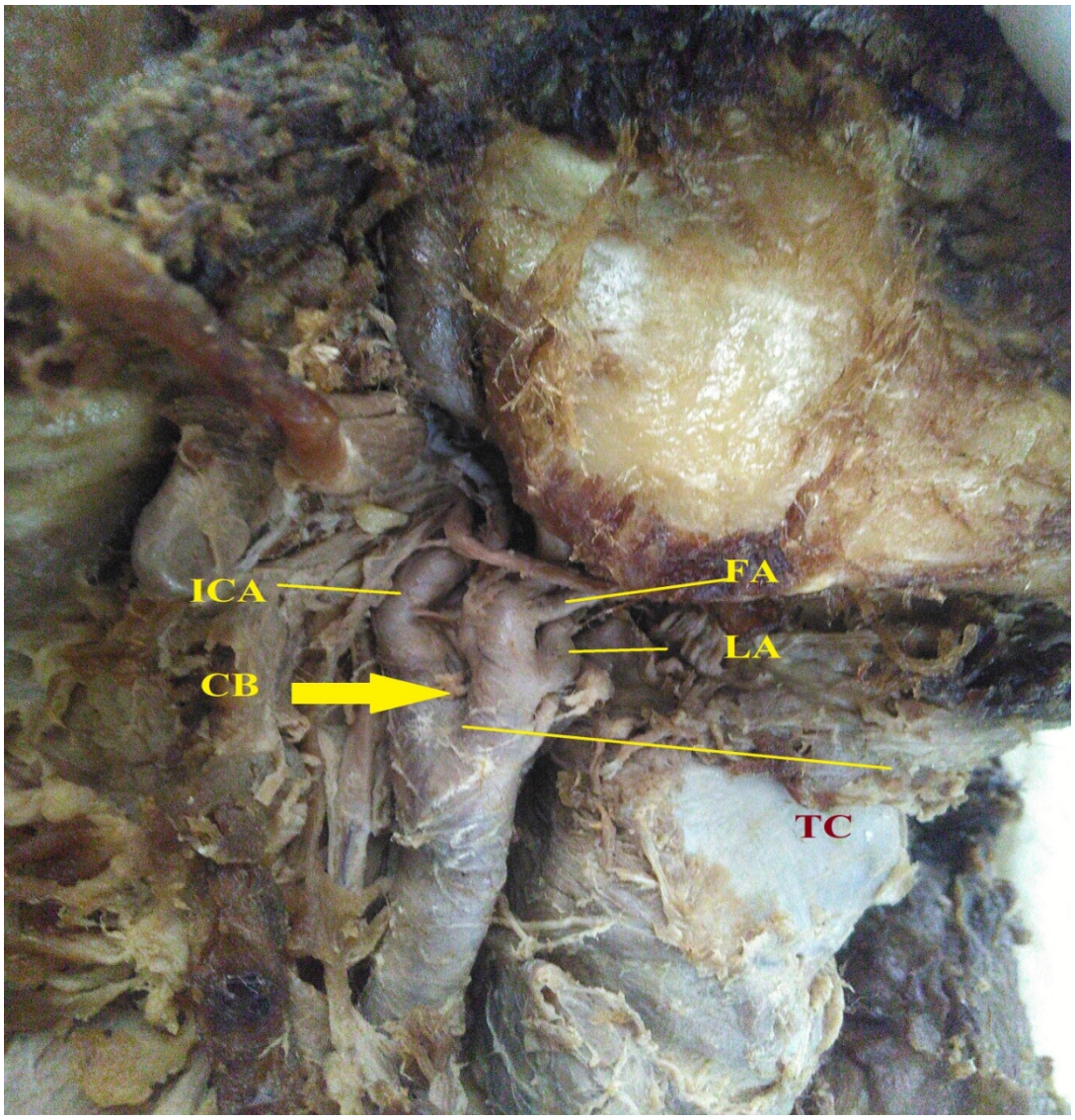


Fig. 4 HIGH ORIGIN OF EXTERNAL CAROTID ARTERY AND ORIGIN OF SUPERIOR THYROID ARTERY FROM CCA

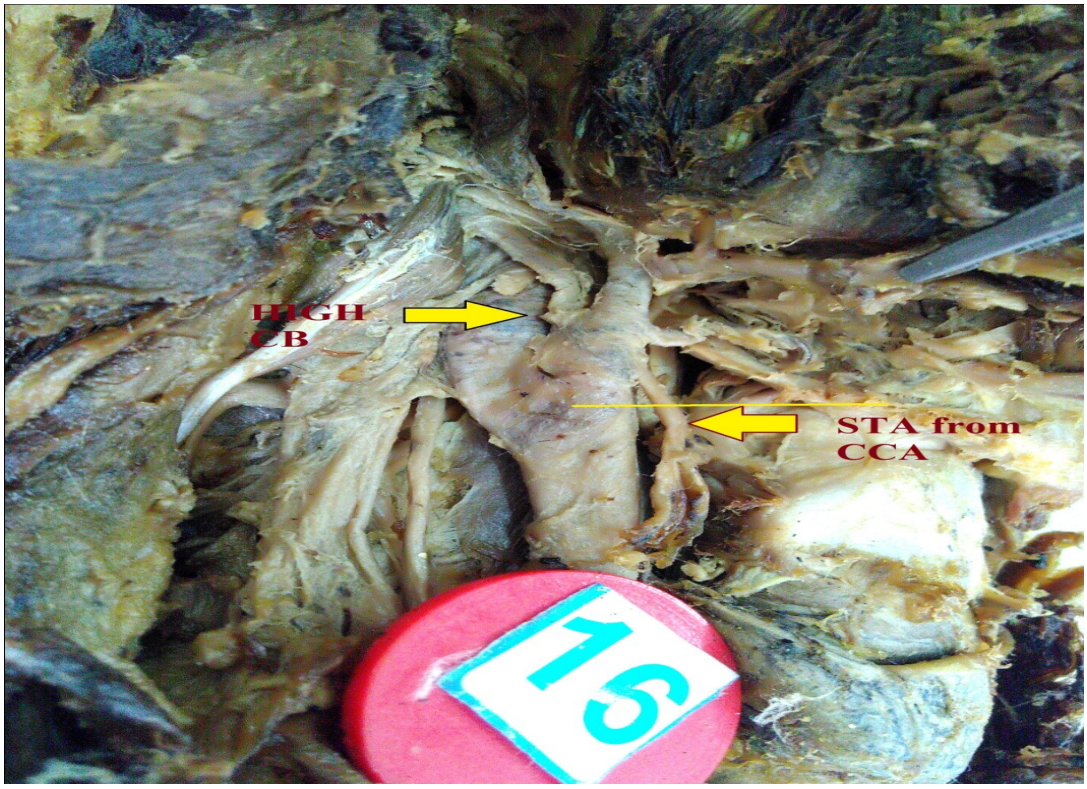


Fig. 5 HIGH ORIGIN OF EXTERNAL CAROTID ARTERY WITH PRESENCE OF LINGUOACIAL TRUNK

This present study of the origin and branching pattern of ECA in 50 hemi-necks reveals the following results.

I) LEVEL OF ORIGIN OF EXTERNAL CAROTID ARTERY (ECA)

The origin of the ECA occurred at the level of the upper border of the lamina of thyroid cartilage (fig- 3),(where the CCA bifurcated), in 46 hemi-necks.

In 4 cases, ECA was found to arise from above the superior border of lamina of thyroid cartilage (fig- 4), 2 on right side and 2 on left side(Table: 1).

Table: 1

ORIGIN OF ECA	FREQUENCY	PERCENTAGE
Upper border of lamina of thyroid cartilage	46	92%
Above superior border of thyroid cartilage	4	8%

Fig. 6 HIGH ORIGIN OF EXTERNAL CAROTID ARTERY WITH ORIGIN OF SUPERIOR THYROID ARTERY FROM CCA

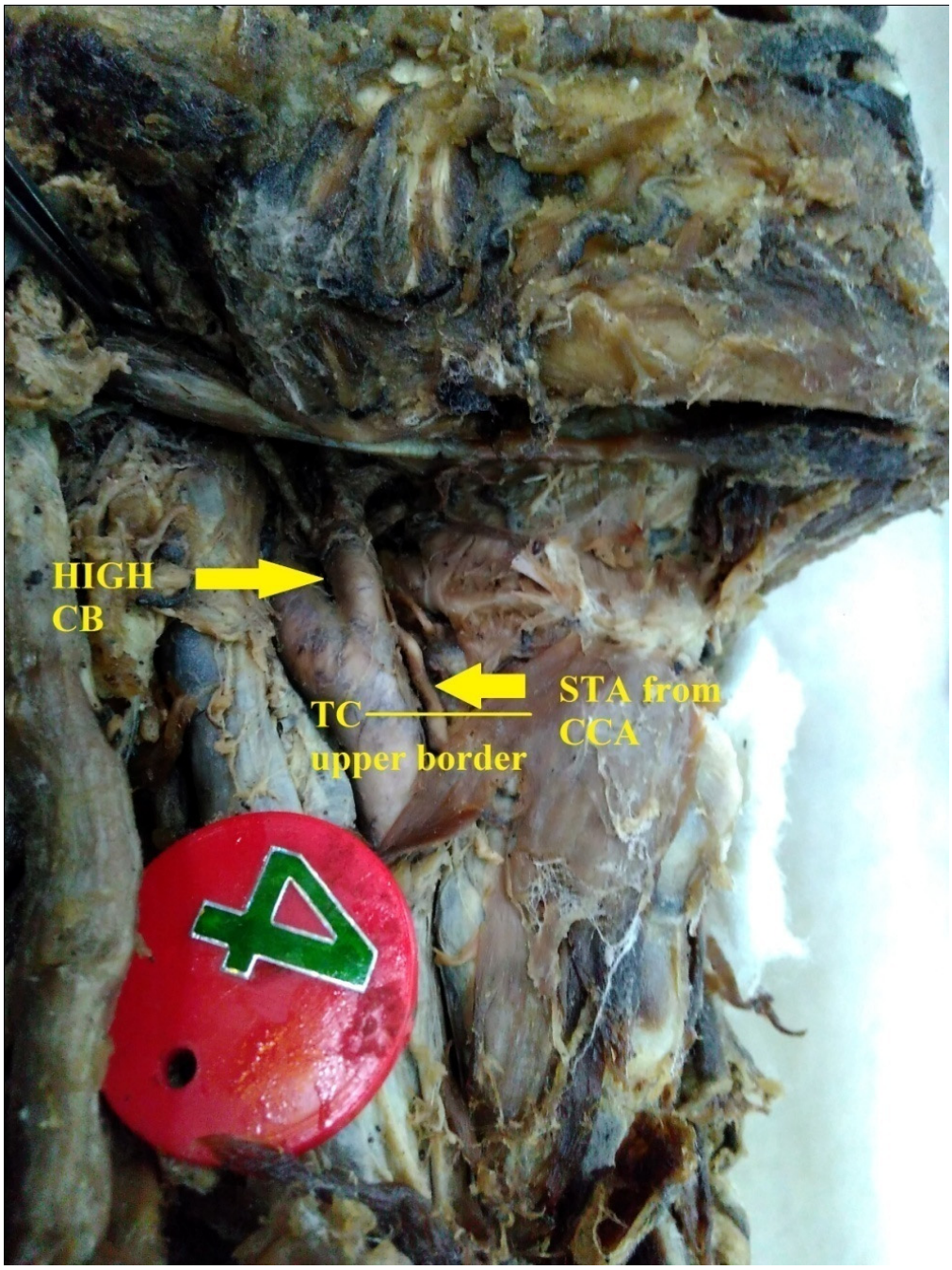


Fig. 7 HIGH ORIGIN OF EXTERNAL CAROTID ARTERY

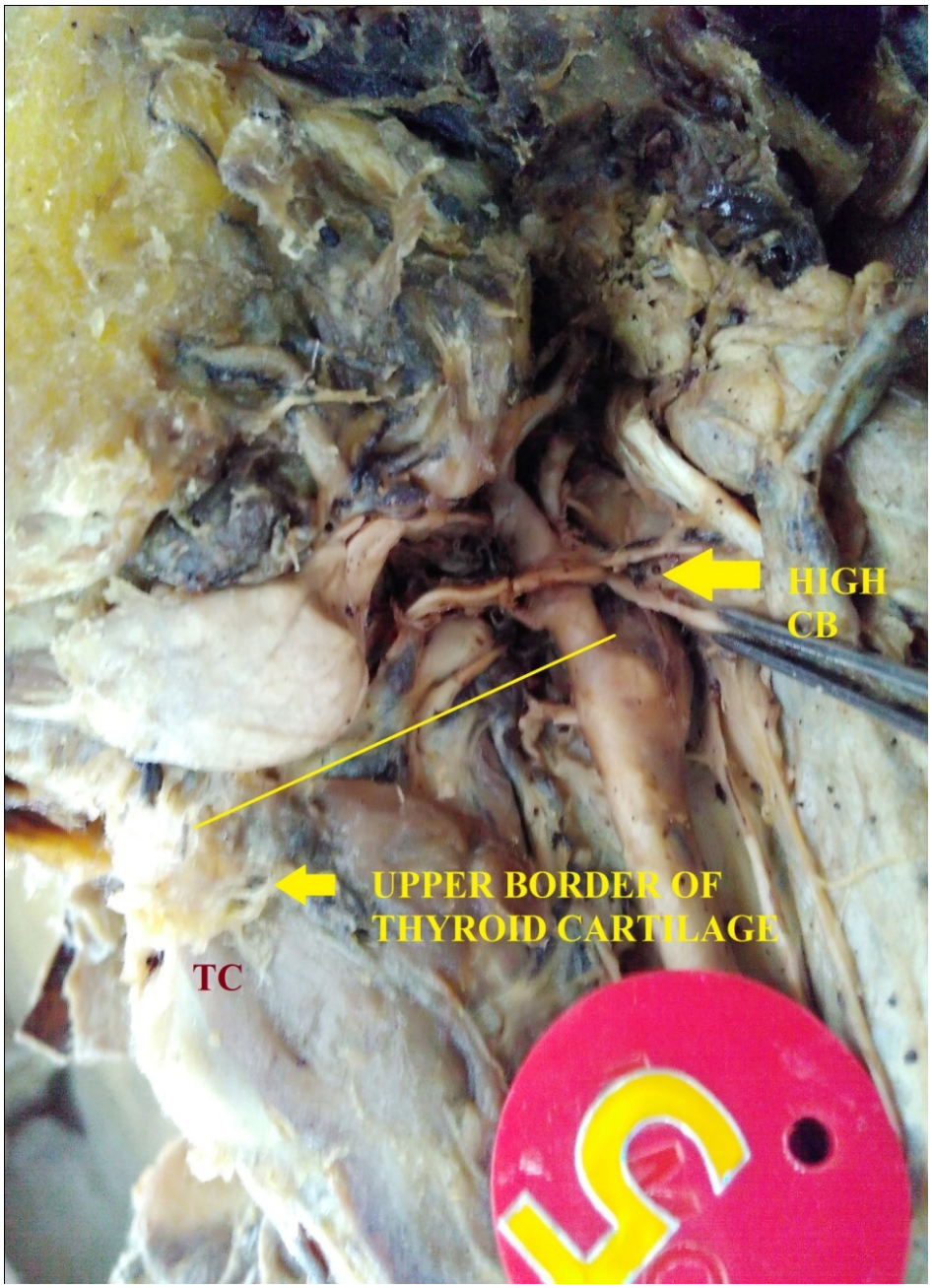
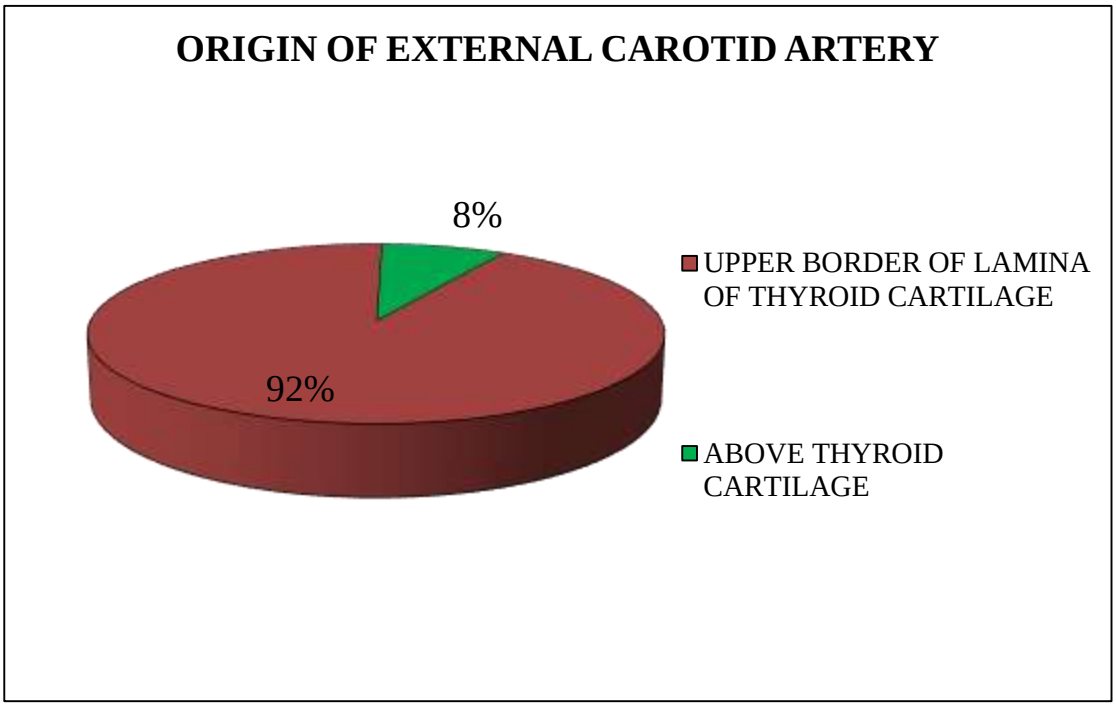


Chart: 1



II) RELATION OF EXTERNAL CAROTID ARTERY WITH INTERNAL CAROTID ARTERY (ICA) IN THE CAROTID TRIANGLE.

In this present study, the ECA, after its origin was presenting anteromedial relation to the ICA, within the carotid triangle in 49 hemineck (fig- 2).

In one hemineck (Table- 2),on the right side, the ECA was lying lateral to ICA within the carotid triangle (fig- 13).

All the branches were emerging from the usual position of ECA and were crossing the ICA superficially to supply their respective territories in the carotid triangle.

Table: 2

RELATION OF ECA WITH ICA	FREQUENCY	PERCENTAGE
Anteromedial	49	98%
Lateral	1	2%

Chart : 2

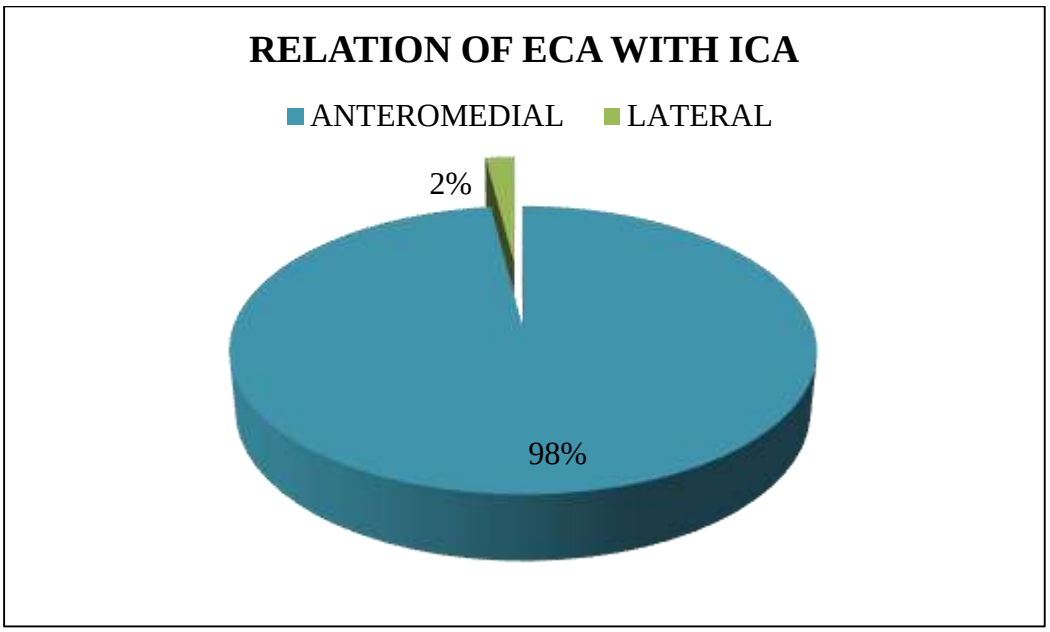


Fig. 8 SUPERIOR THYROID ARTERY AT THE LEVEL OF CAROTID BIFURCATION

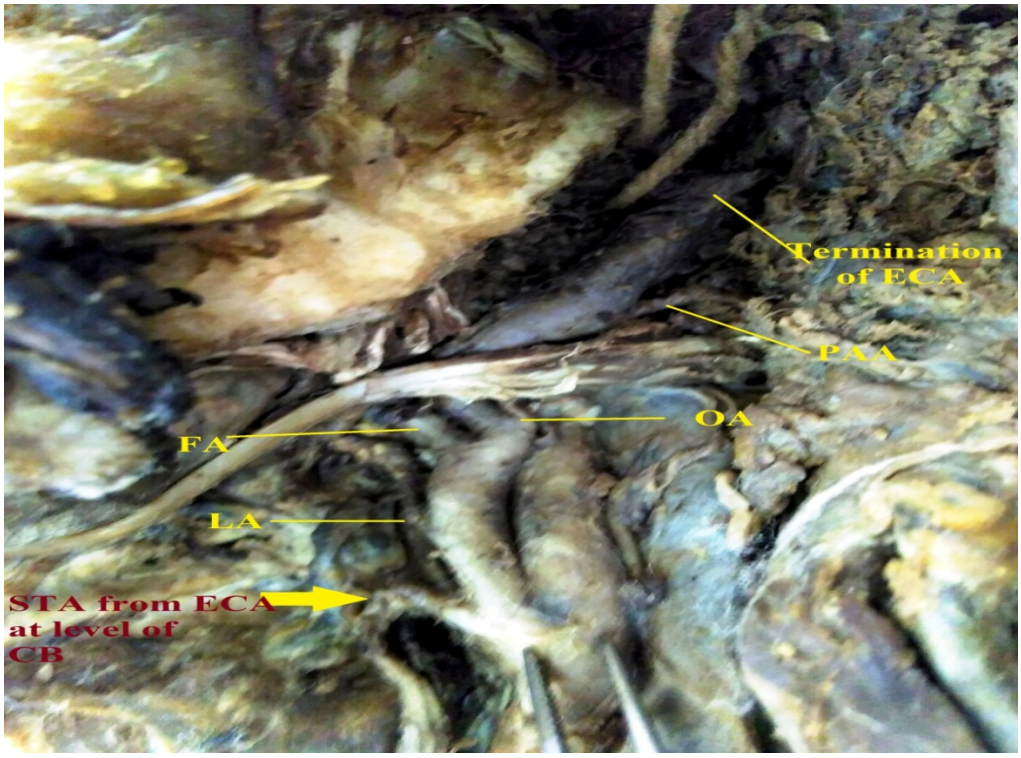
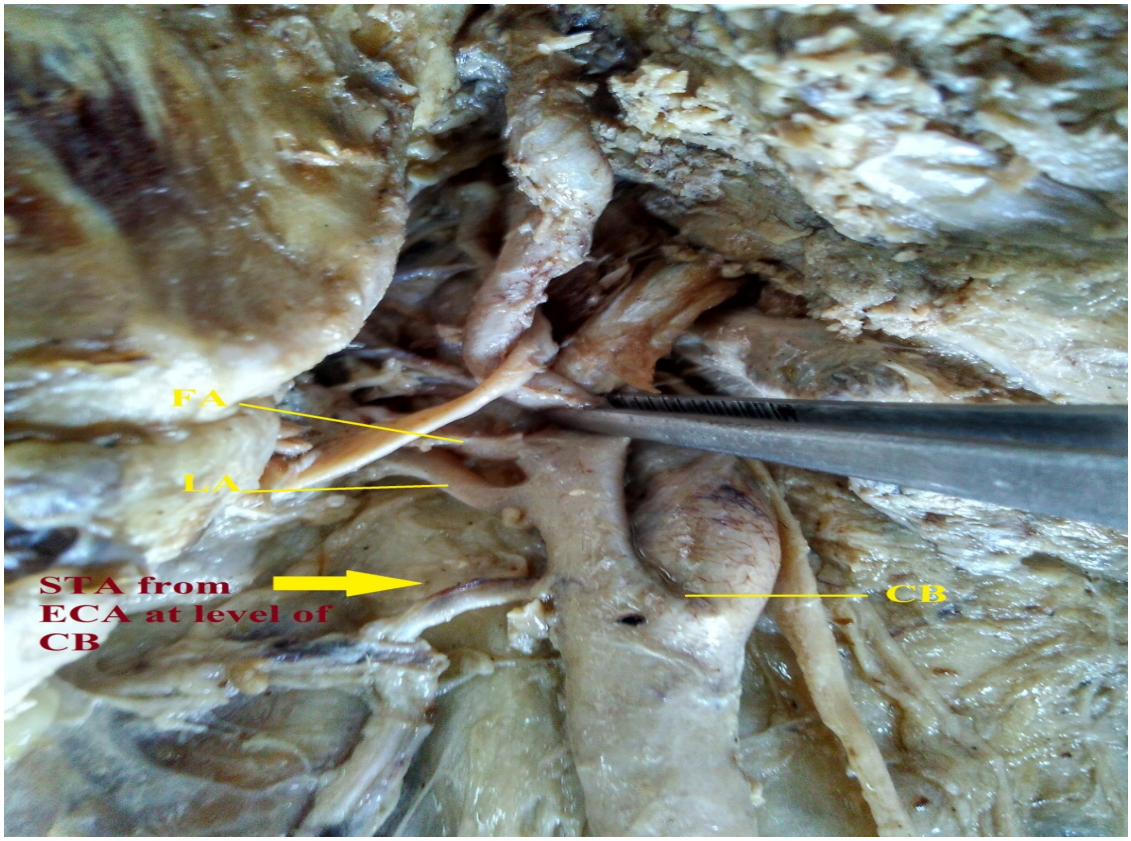


Fig. 9



III) LEVEL OF ORIGIN OF SUPERIOR THYROID ARTERY (STA)

In this study, the superior thyroid artery originated from the anterior surface of ECA, in 29 heminecks(fig- 11). 13 cases were showing the STA to arise from ECA at the level of carotid bifurcation (fig- 8). In 6 specimens, the STA arose directly from the CCA, just below the bifurcation(fig- 10).

In 2 heminecks, they arose from the level of the tip of the greater cornu of the hyoid bone, as thyrolingual trunk (fig- 20), in common with the lingual artery.

Table: 3

ORIGIN OF STA	FREQUENCY	PERCENTAGE
From ECA	29	58%
From level of CB	13	26%
Thyrolingual trunk	2	4%
From CCA	6	12%

Among the 2 thyrolingual trunks, one was from the right side and one was from the left side, in 2 cadavers.

Fig. 10 SUPERIOR THYROID ARTERY FROM COMMON CAROTID ARTERY

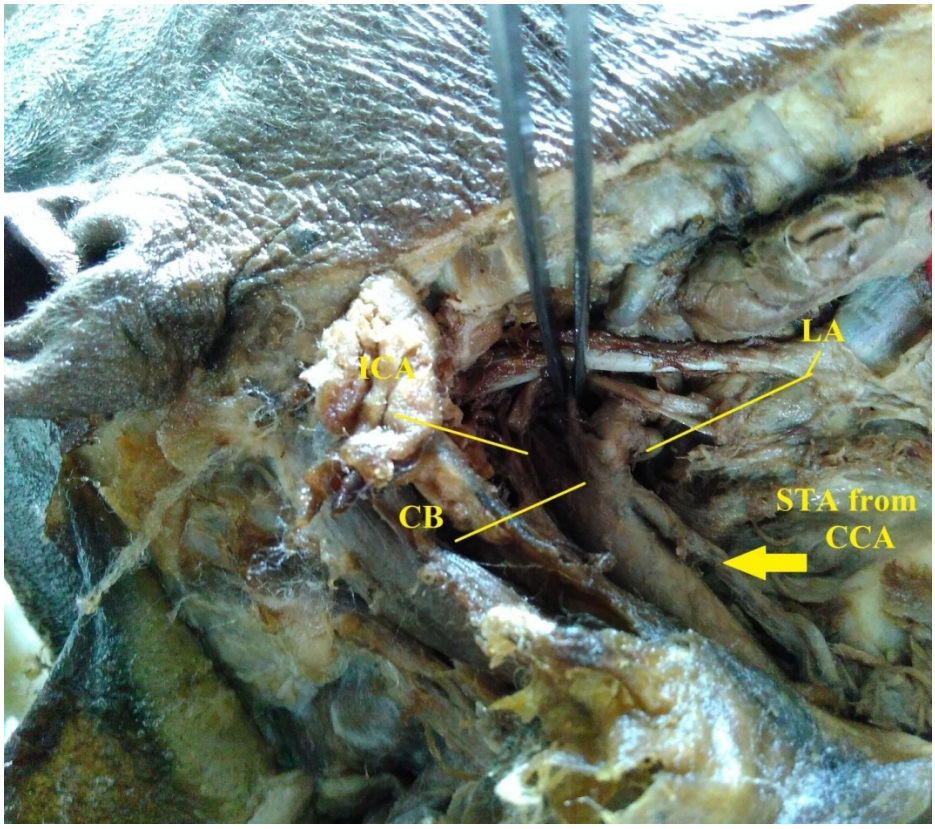


Fig. 11 SUPERIOR THYROID ARTERY FROM THE EXTERNAL CAROTID ARTERY

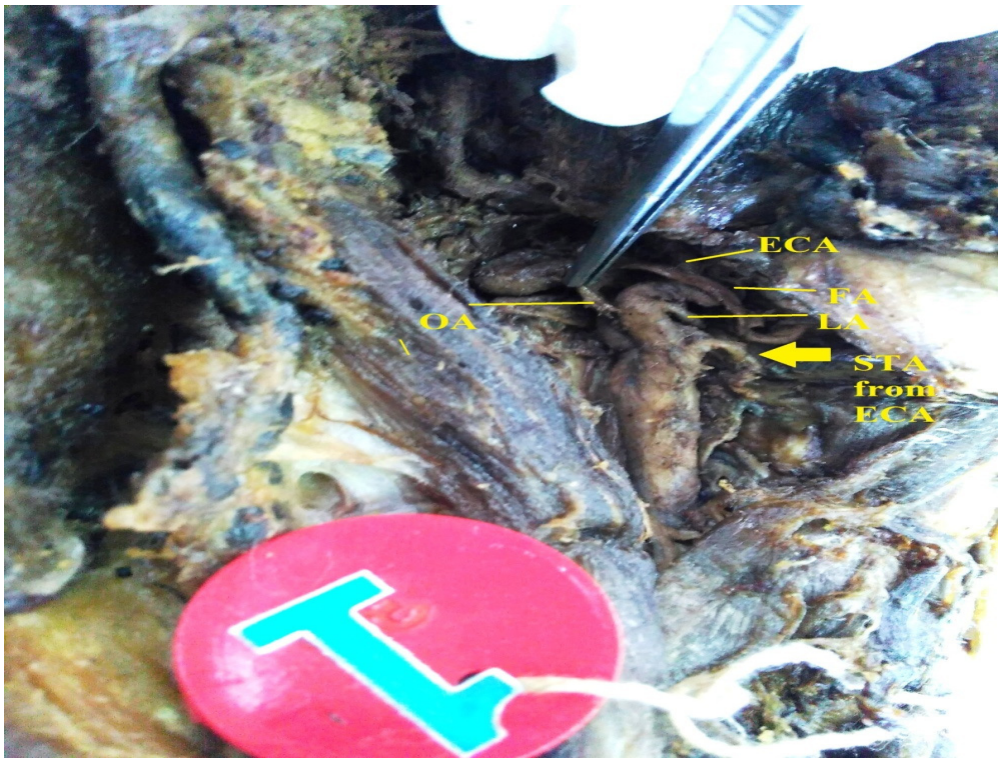
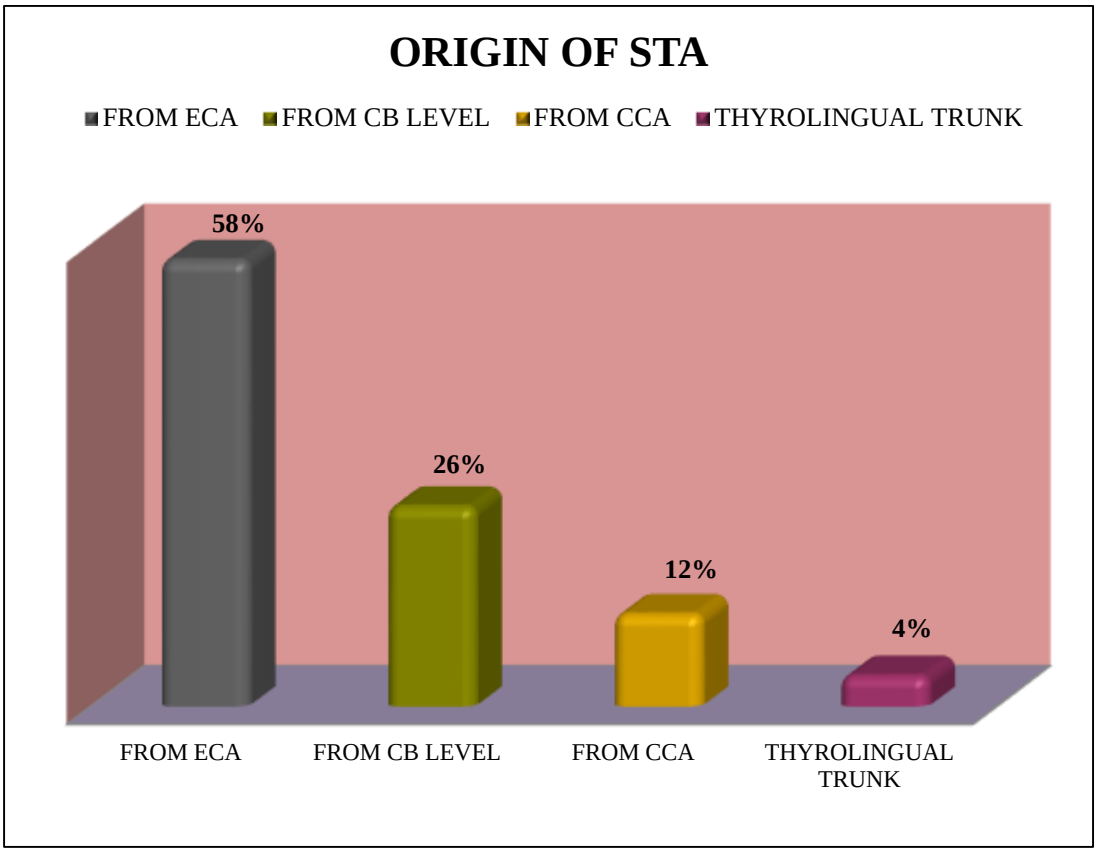


Table: 4

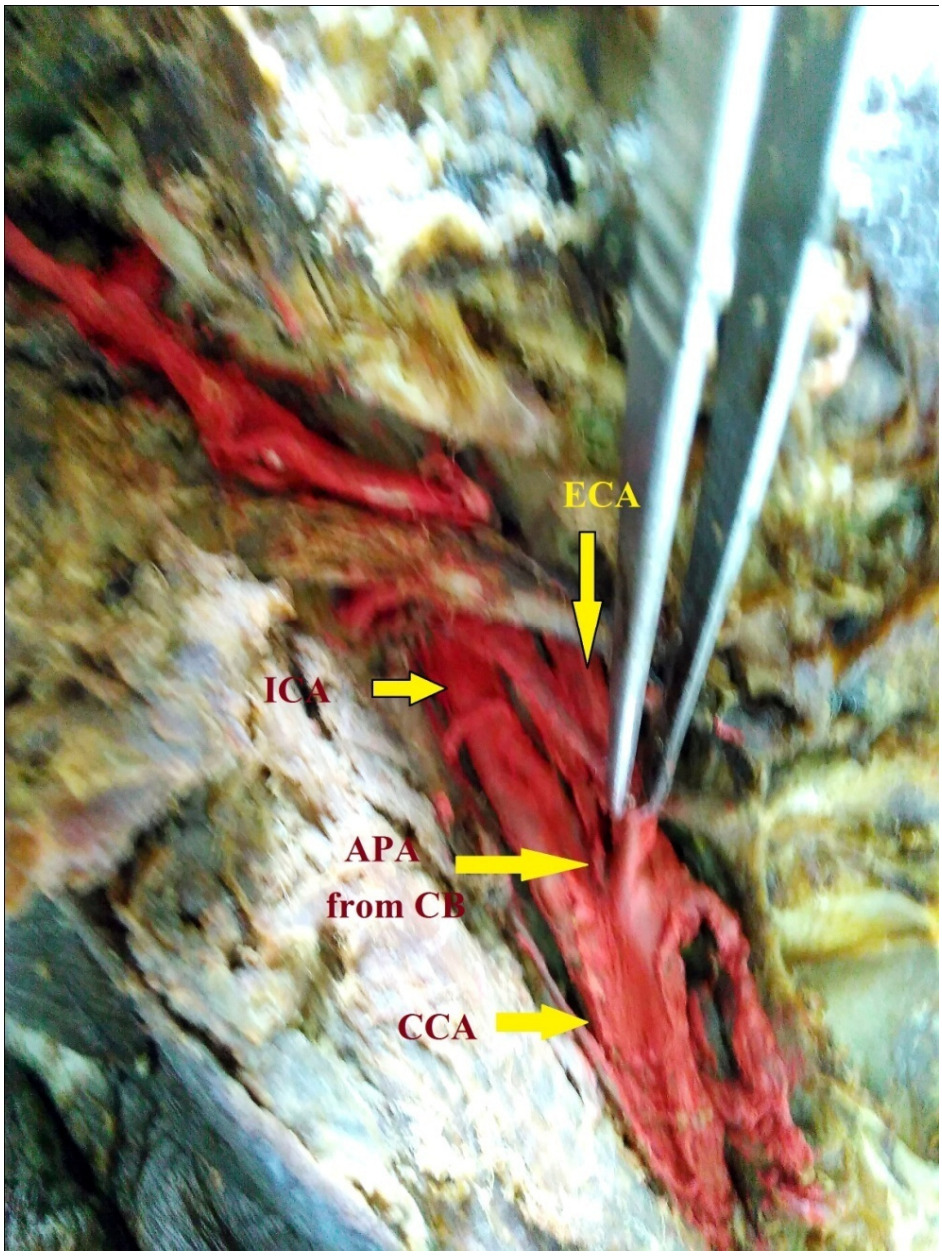
PATTERN OF ORIGIN OF STA	FREQUENCY	PERCENTAGE
Separate branch	48	96%
Thyrolingual trunk	2	4%

Chart : 3



The superior thyroid artery emerged as separate branches from ECA, carotid bifurcation and common carotid artery in 96% of cases (Table: 4).

Fig. 12 ASCENDING PHARYNGEAL ARTERY FROM CAROTID BIFURCATION



IV) LEVEL OF ORIGIN OF ASCENDING PHARYNGEAL ARTERY (APA)

The ascending pharyngeal artery, was arising from the medial surface of ECA near its origin, in all the 49 specimens(Table- 5).

Only in one case, its origin was from CB .(Fig- 12)

Table: 5

ORIGIN OF ASCENDING PHARYNGEAL ARTERY	FREQUENCY	PERCENTAGE
From the medial surface of ECA	49	98%
From the CB level	1	2%

Chart: 4

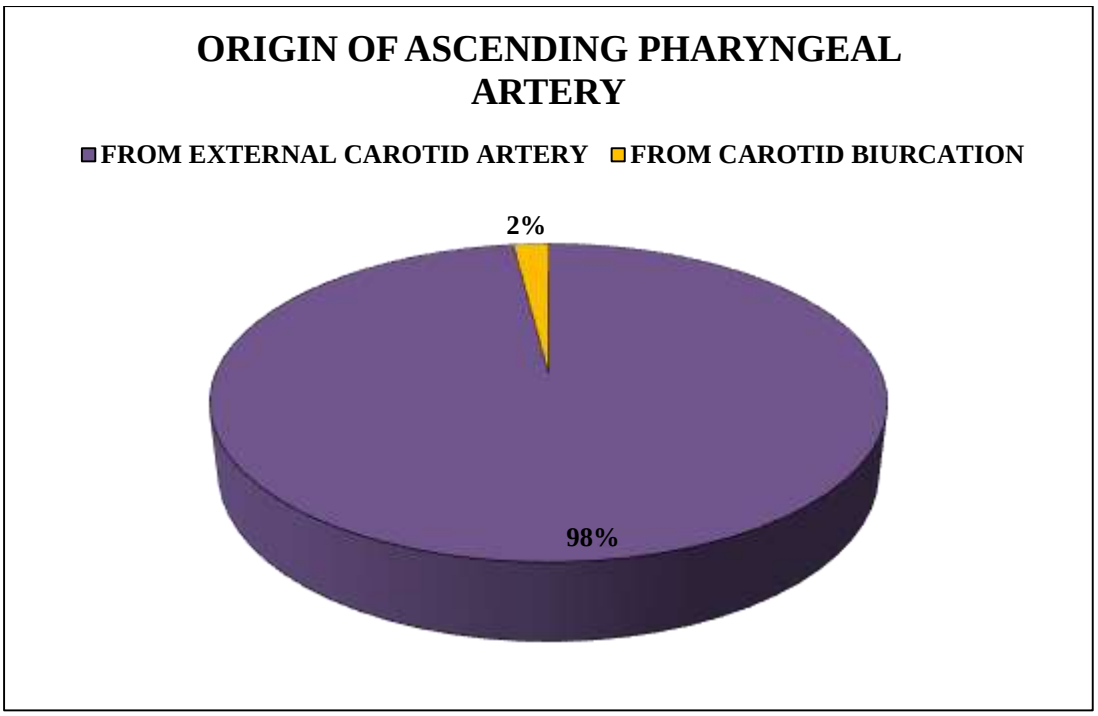


Fig. 13 LATERAL DISPOSITION OF EXTERNAL CAROTID ARTERY IN RELATION WITH INTERNAL CAROTID ARTERY

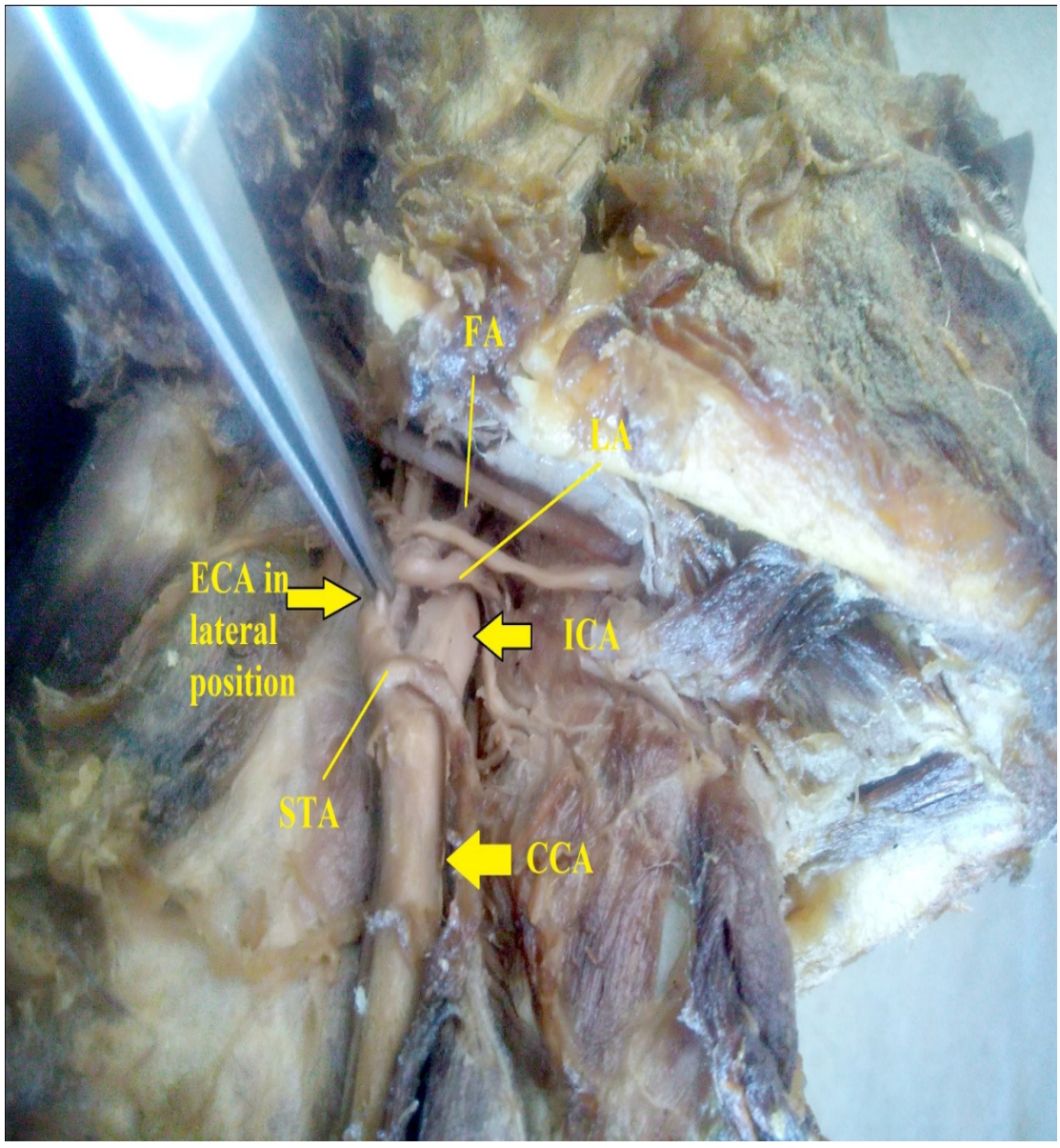
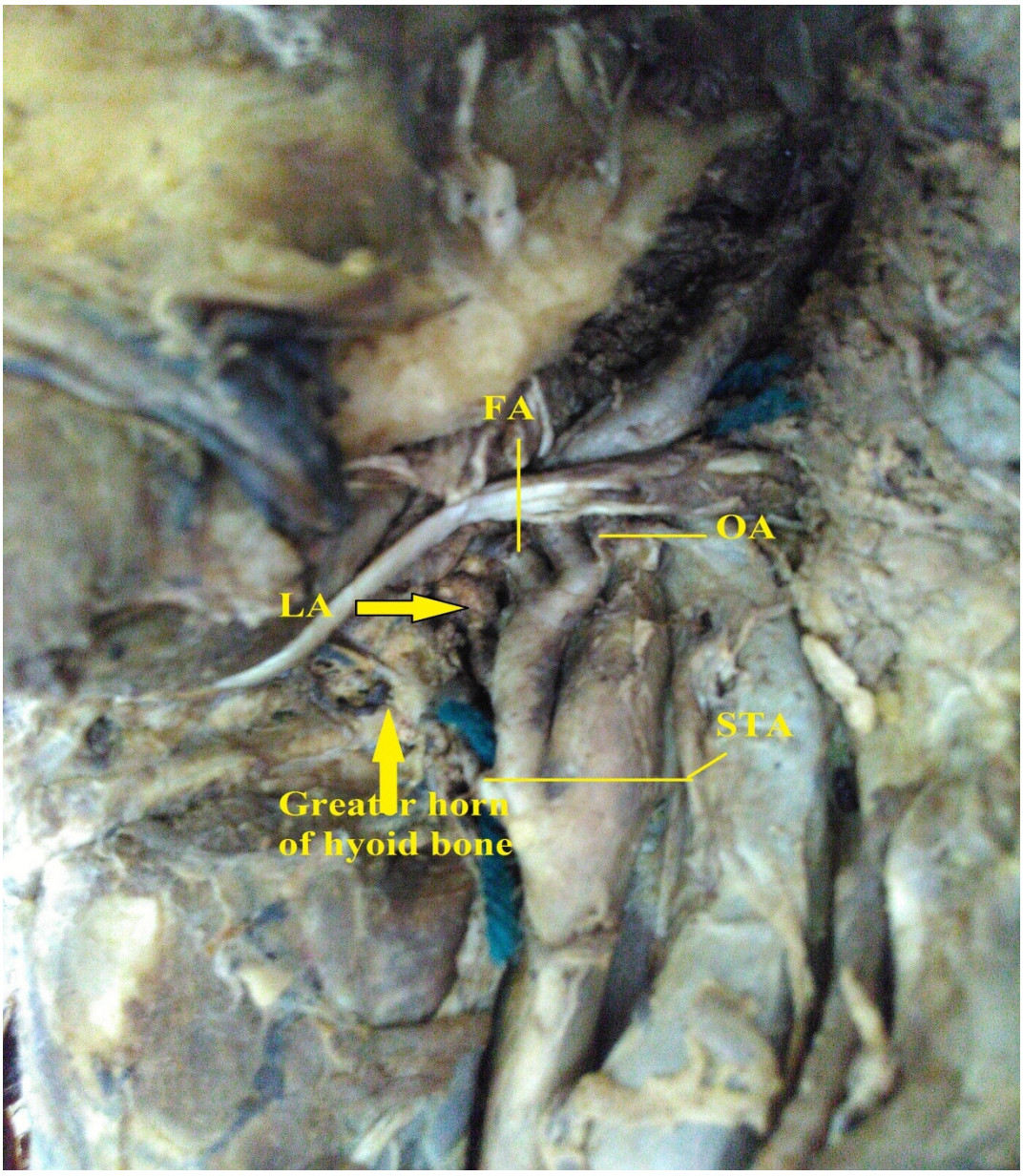


Table: 6

PATTERN OF ORIGIN OF APA	FREQUENCY	PERCENTAGE
Separate branch	50	100%
Common trunk	Nil	_

All the specimens were observed to have the Ascending pharyngeal artery as separate branches arising from External carotid artery.

Fig. 14 LINGUAL ARTERY AT LEVEL OF GREATER CORNU OF HYOID BONE



V) LEVEL OF ORIGIN OF LINGUAL ARTERY

The lingual artery originated from the ECA opposite to the greater cornu of the hyoid bone, in 46 heminecks (Fig- 14).

In 4 heminecks (Table- 7), it arose from below the tip of the greater cornu of the hyoid bone (Fig- 15).

Table: 7

LEVEL OF ORIGIN OF LINGUAL ARTERY	FREQUENCY	PERCENTAGE
At the level of the greater cornu of hyoid bone	46	92%
Below the level of the greater cornu of hyoid bone	4	8%

The branching pattern varied from separate branches to common trunks. The lingual artery originated as separate branch from ECA in 37 heminecks.

In 2 specimens, they were arising as common thyrolingual trunk, and in 11 heminecks, they originated as linguofacial trunk, in common with facial artery. (Fig-17, 18).

Fig. 15 LINGUAL ARTERY BELOW GREATER CORNU OFHYOID BONE

Fig. 16

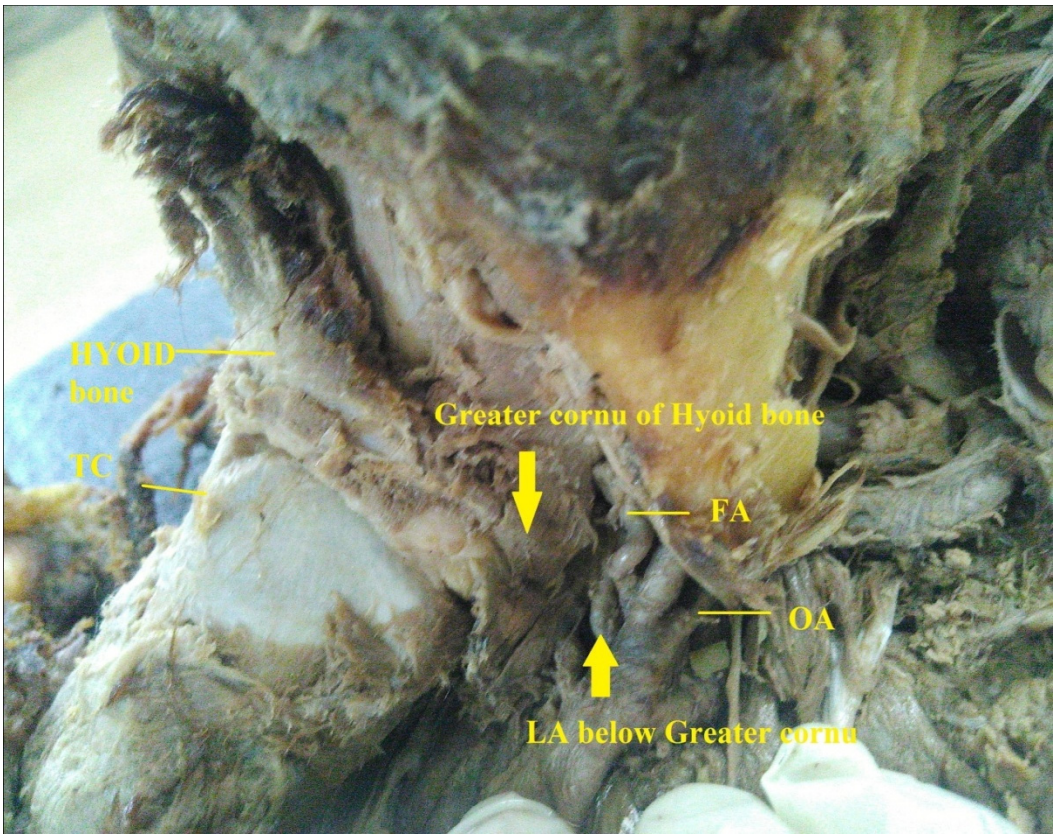


Table: 8

PATTERN OF ORIGIN OF LINGUAL ARTERY	FREQUENCY	PERCENTAGE
Separate branch from ECA	37	74%
Thyrolingual trunk	2	4%
Linguofacial trunk	11	22%

In 5 specimens, the linguofacial trunks were from the right side and in 6 cases it were from left side. The most commonest variation noted in the present study was the presence of the linguofacial trunk, while the rare variation of thyrolingual trunk was also observed (Table- 8).

Chart: 5

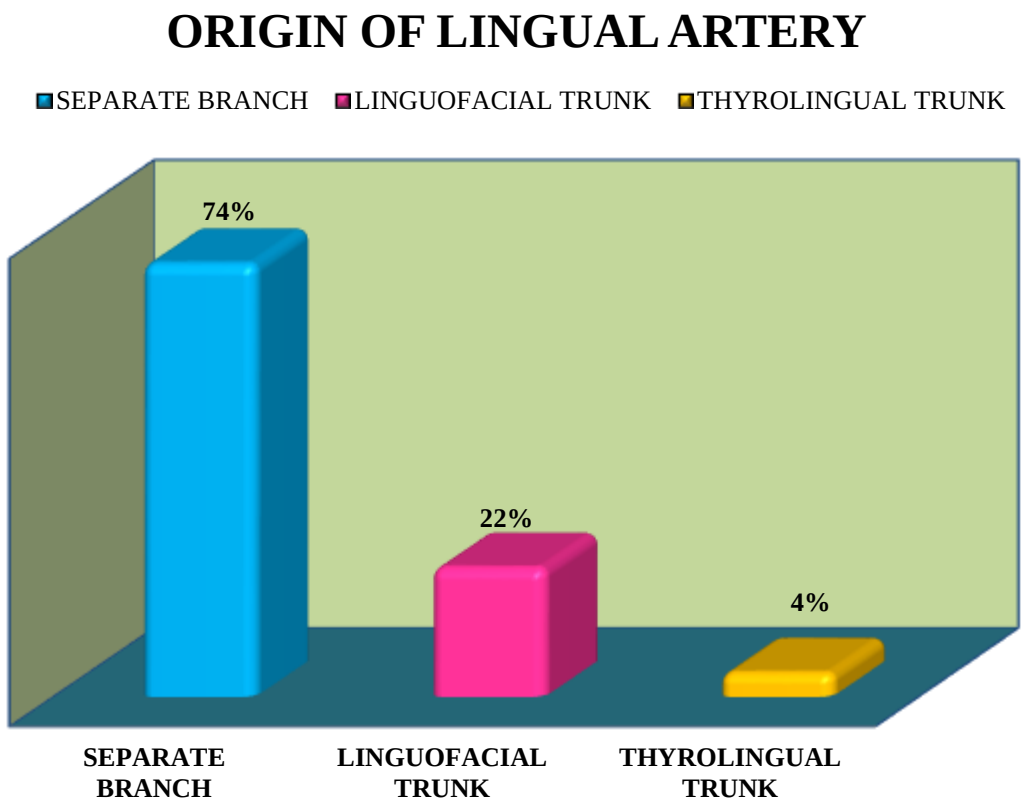
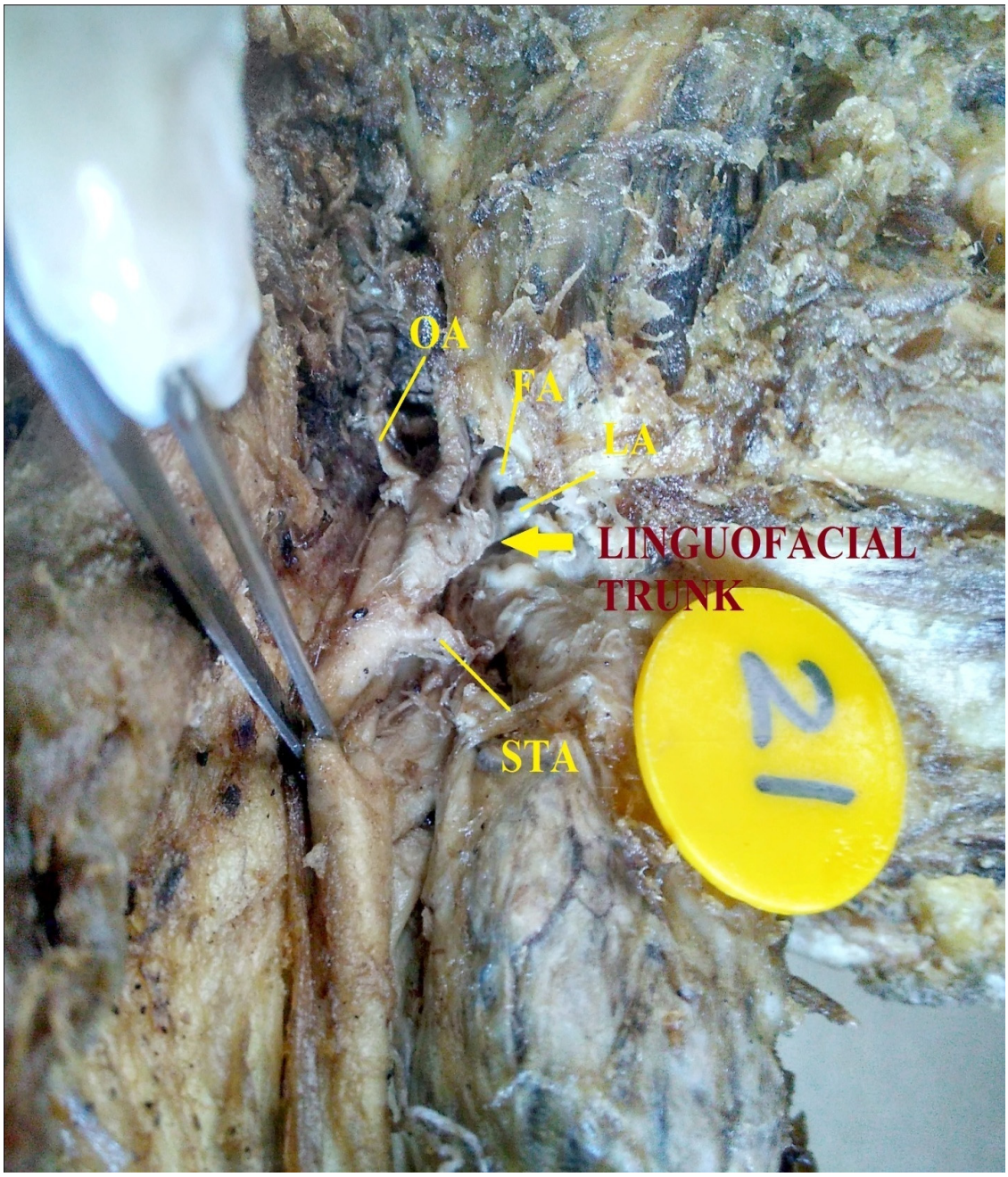


Fig. 17 LINGUOFACIAL TRUNK



Compared to the other branches of External carotid artery, Lingual artery was the branch which showed the less number of separate branches emerging from its parent

VI) LEVEL OF ORIGIN OF FACIAL ARTERY (FA)

In this current study, the facial artery arose as separate branch from the anterior surface of the ECA, immediately above the level of the greater cornu of hyoid bone, in 39 hemineck specimens. (Fig- 3).

Whereas, in remaining 11 hemineck specimens (Table- 9), the FA, originated as linguofacial trunk. (Fig- 5)

Table: 9

PATTERN OF ORIGIN OF FACIAL ARTERY	FREQUENCY	PERCENTAGE
As separate branch	39	78%
Linguofacial trunk	11	22%

Fig. 18 LINGUOFACIAL TRUNK

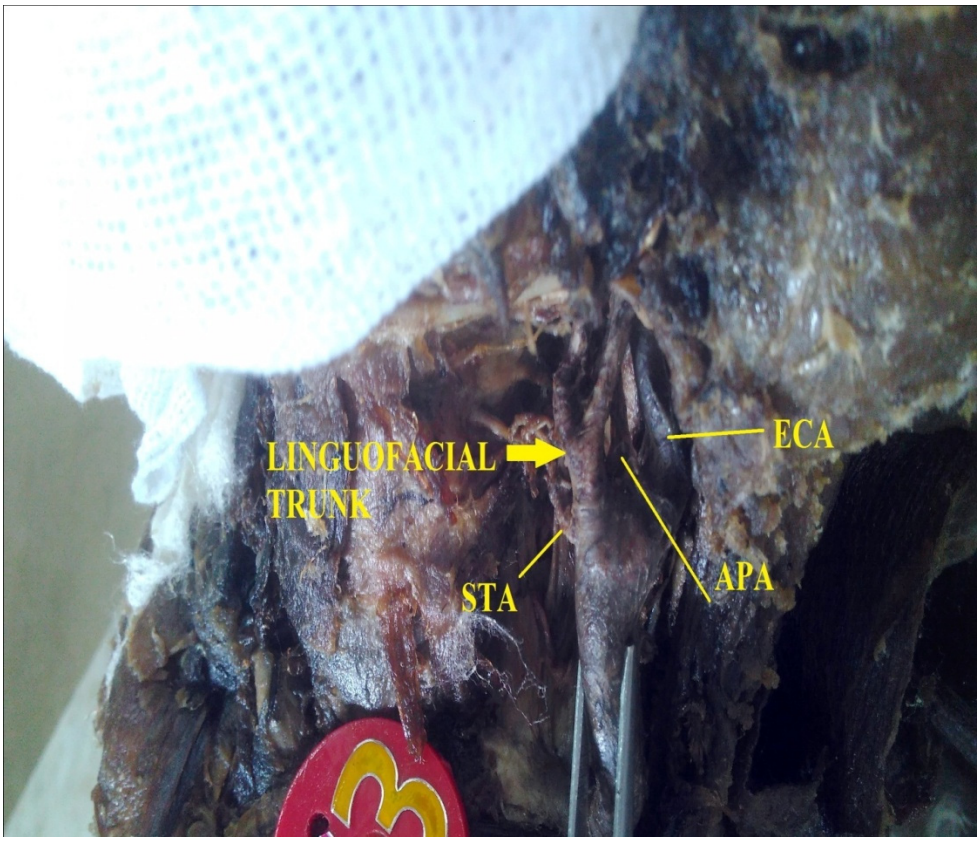


Fig. 19

Fig. 20 THYROLINGUAL TRUNK

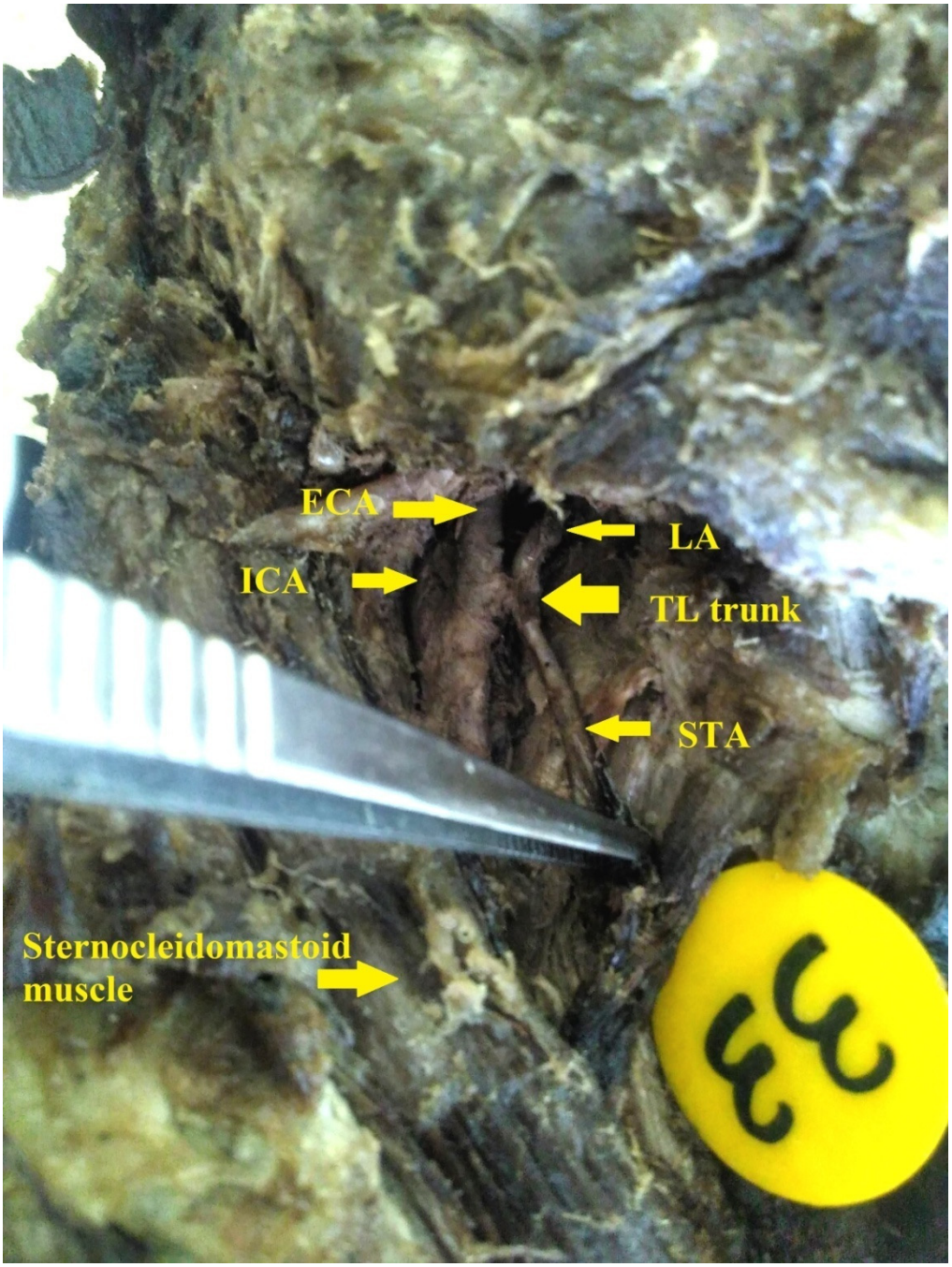
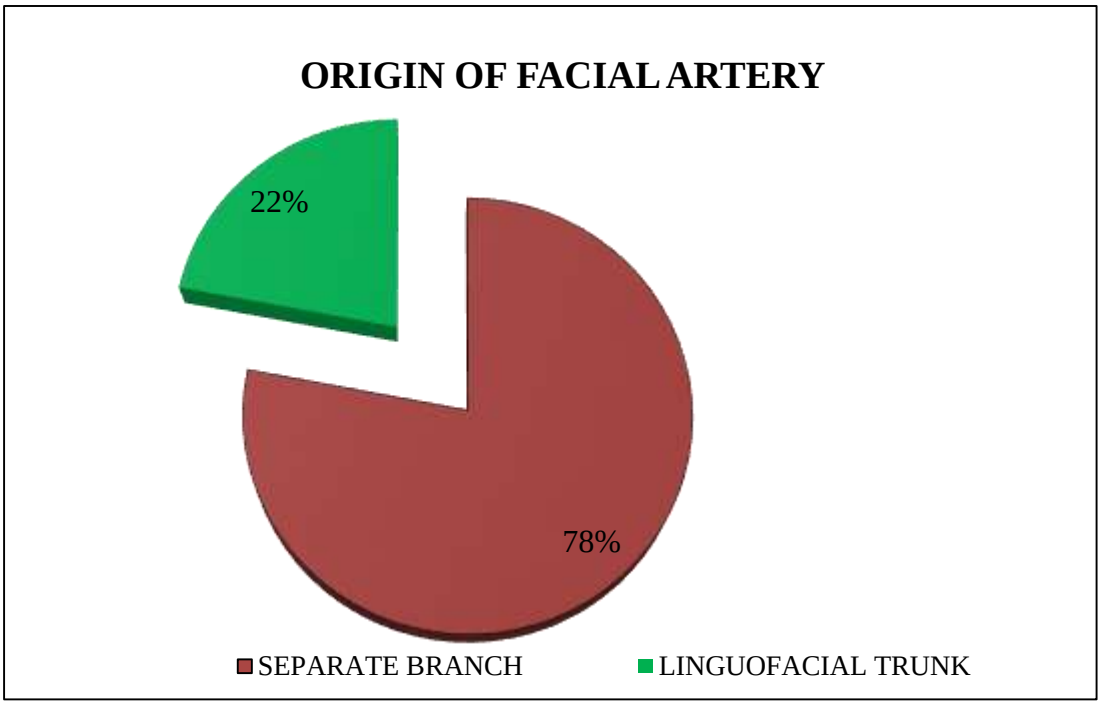


Chart: 6



Next to Lingual artery, the Facial artery was showing less number of separate branches from External carotid artery.

Fig. 21 OCCIPITAL ARTERY ARISING BELOW LEVEL OF FACIAL ARTERY

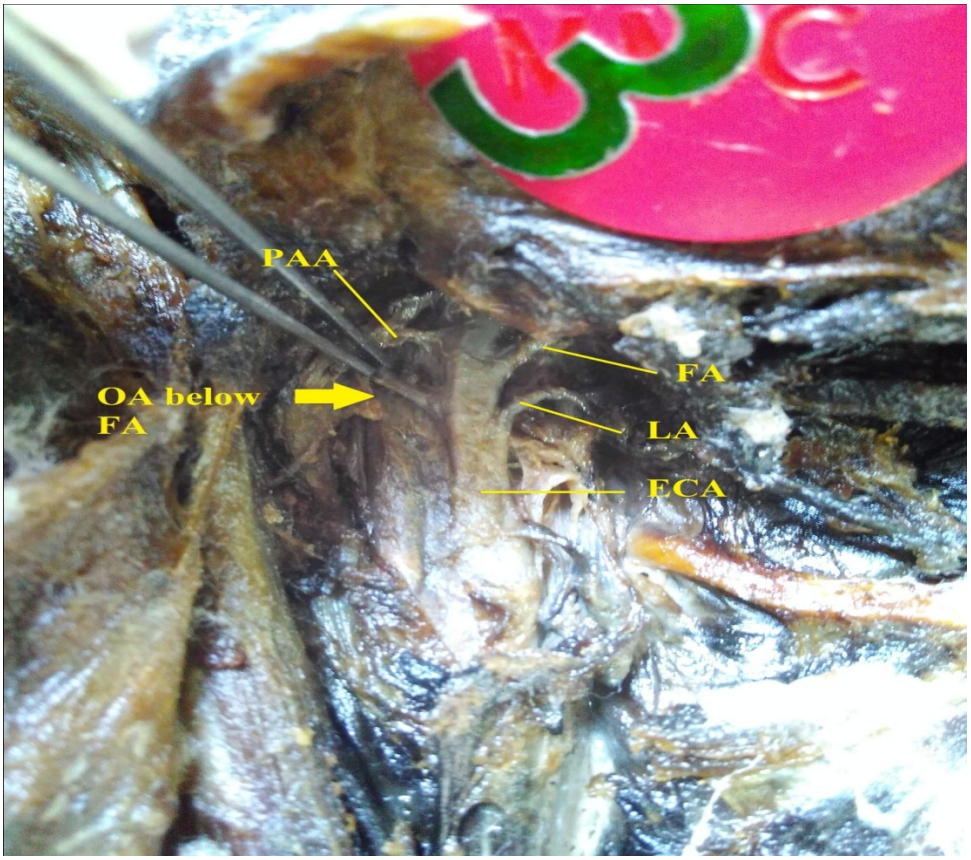
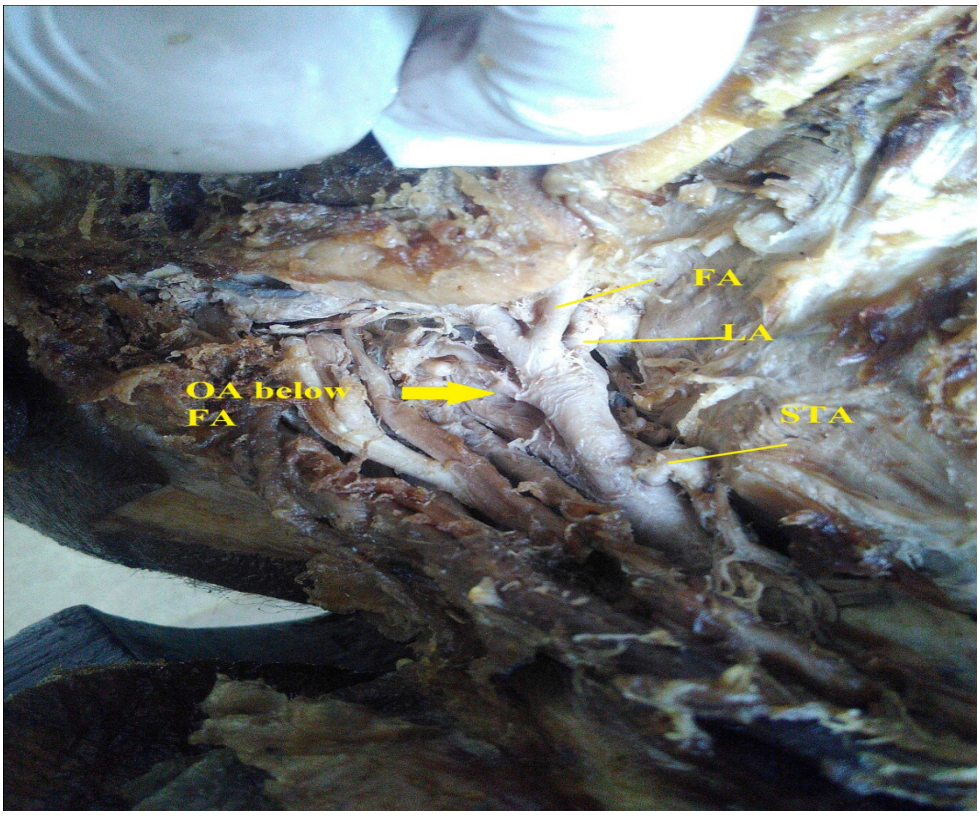


Fig. 22



VII) LEVEL OF ORIGIN OF OCCIPITAL ARTERY (OA)

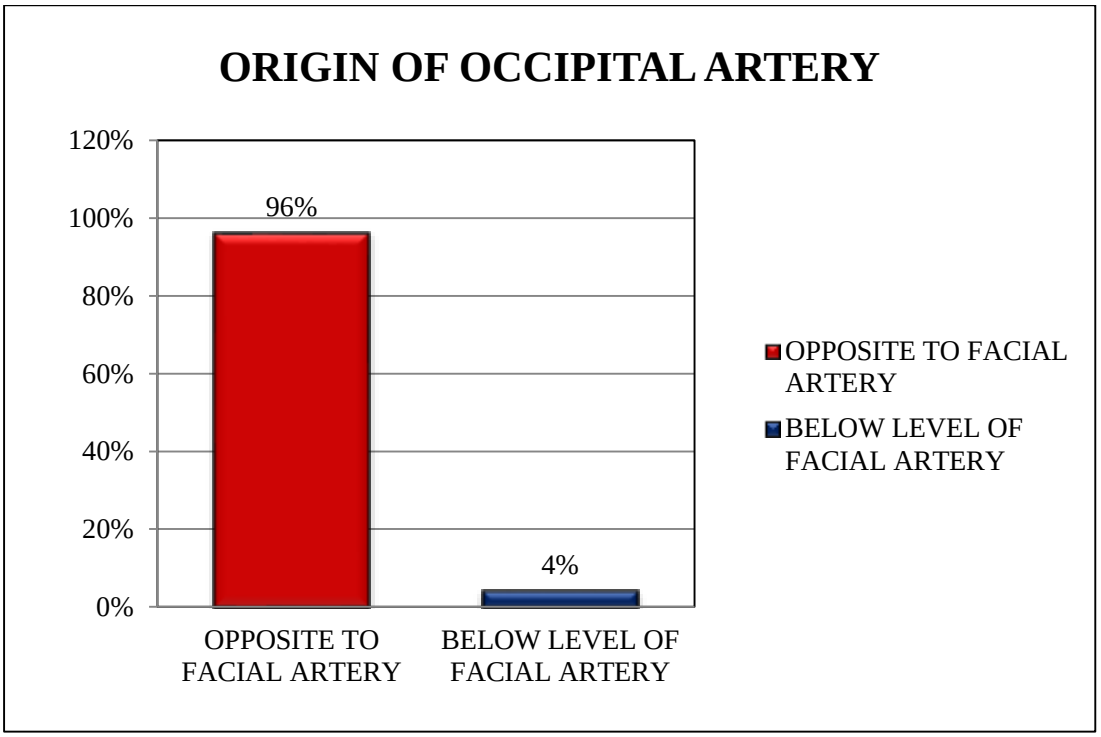
In this study, the occipital artery arose from the posterior surface of the ECA, at the level of FA in 48 specimens (Fig- 11).

In 2 cadavers (Table- 10), on one side, they were arising below the level of facial artery, i.e., almost at the hyoid bone level. (Fig- 22). Both the variations were from the right side.

Table: 10

ORIGIN OF OCCIPITAL ARTERY	FREQUENCY	PERCENTAGE
At the level of facial artery	48	96%
Below the level of facial artery.	2	4%

Chart: 7



All the specimens showed separate branches of occipital artery arising from the External carotid artery (Table- 11). No common trunks was noted with respect to the occipital artery.

Table: 11

PATTERN OF ORIGIN OF OA	FREQUENCY	PERCENTAGE
Separate branch	50	100%
Common trunks	Nil	_

Fig. 23 POSTERIOR AURICULAR ARTERY

VIII) LEVEL OF ORIGIN OF POSTERIOR AURICULAR ARTERY

In the current study, ECA, gave rise to posterior auricular artery from its posterior surface, above the posterior belly of Digastric muscle and Stylohyoid muscle, in all the 50 specimens. (Fig- 23)

Table: 12

ORIGIN OF POSTERIOR AURICULAR ARTERY(PAA)	FREQUENCY	PERCENTAGE
From ECA, above digastric muscle.	50	100%
Other levels	Nil	_

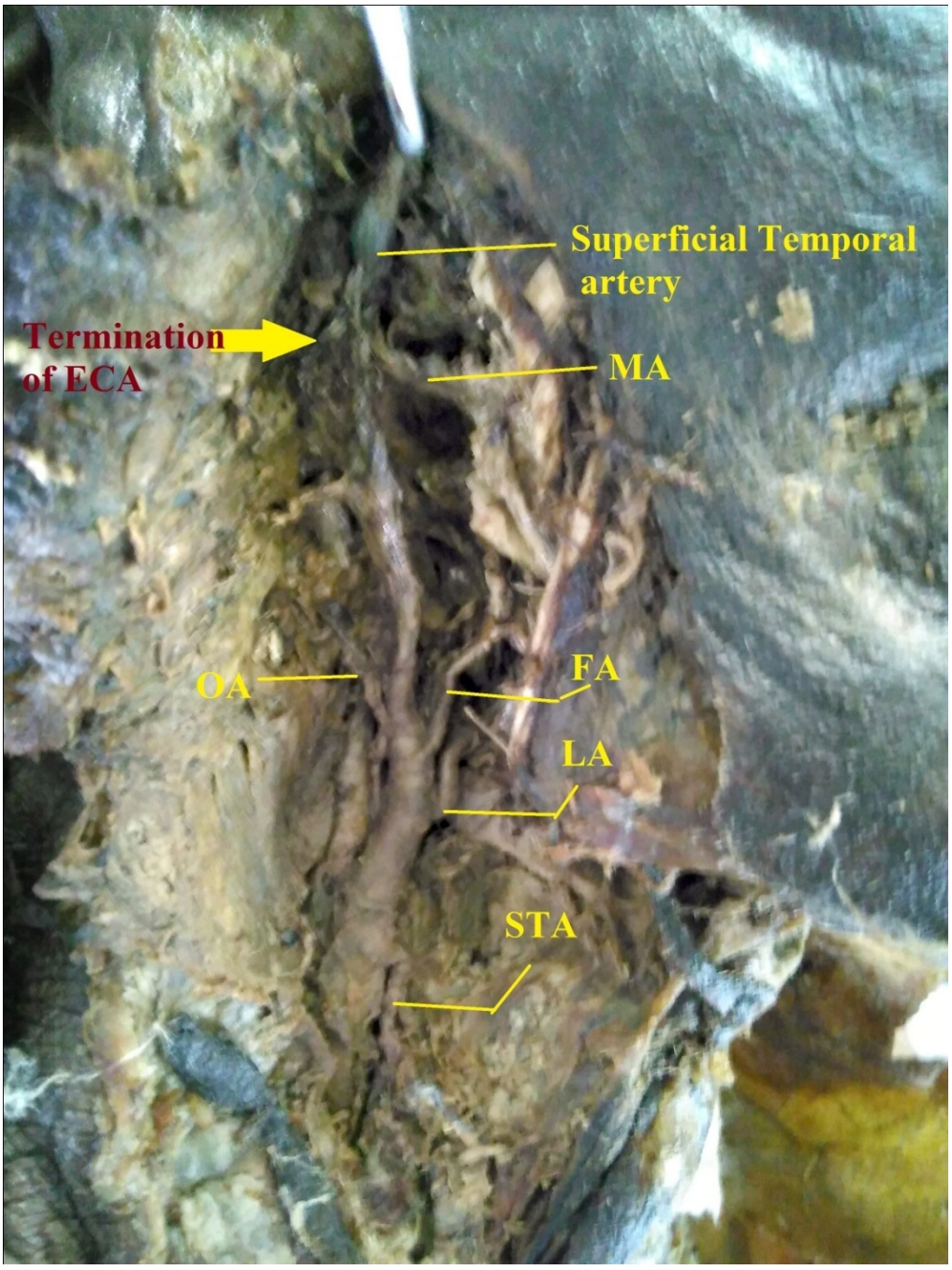
Posterior auricular artery, from all specimens were originating as separate branches from the posterior aspect of the External carotid artery (Table- 13). Occipito-auricular trunk is a common trunk, where posterior auricular artery arises in common with occipital artery.

Table: 13

PATTERN OF ORIGIN OF PAA	FREQUENCY	PERCENTAGE
Separate branch	50	100%
Common trunks	Nil	_

In the present study no common trunk branches were observed.

Fig. 24 TERMINATION OF EXTERNAL CAROTID ARTERY



IX) LEVEL OF TERMINATION OF ECA

In this present study, ECA terminated into the superficial temporal artery and the maxillary artery, in all the 50 heminecks.

The termination of ECA, occurred as bifurcation pattern, into the above said arteries, within the parotid gland, in all the cadavers opposite to the neck of the mandible. (Fig- 24)

Table: 14

TERMINATION OF ECA	FREQUENCY	PERCENTAGE
Opposite to neck of the mandible	50	100%
Other levels	Nil	_

In this present study, the pattern of termination of ECA is only as bifurcation, in all the cases.

Table: 15

PATTERN OF TERMINATION OF ECA	FREQUENCY	PERCENTAGE
Bifurcation	50	100%
Others	Nil	_

The present study showed the maxillary artery to arise at the level of the neck of the mandible as separate branches, in all cases (Table- 14)

Table: 16

ORIGIN OF MAXILLARY ARTERY	FREQUENCY	PERCENTAGE
Behind the neck of mandible	50	100%
Others	NIL	_

Fig. 25 MAXILLARY ARTERY AND SUPERICIAL TEMPORAL ARTERYAT LEVEL OF NECK OF MANDIBLE

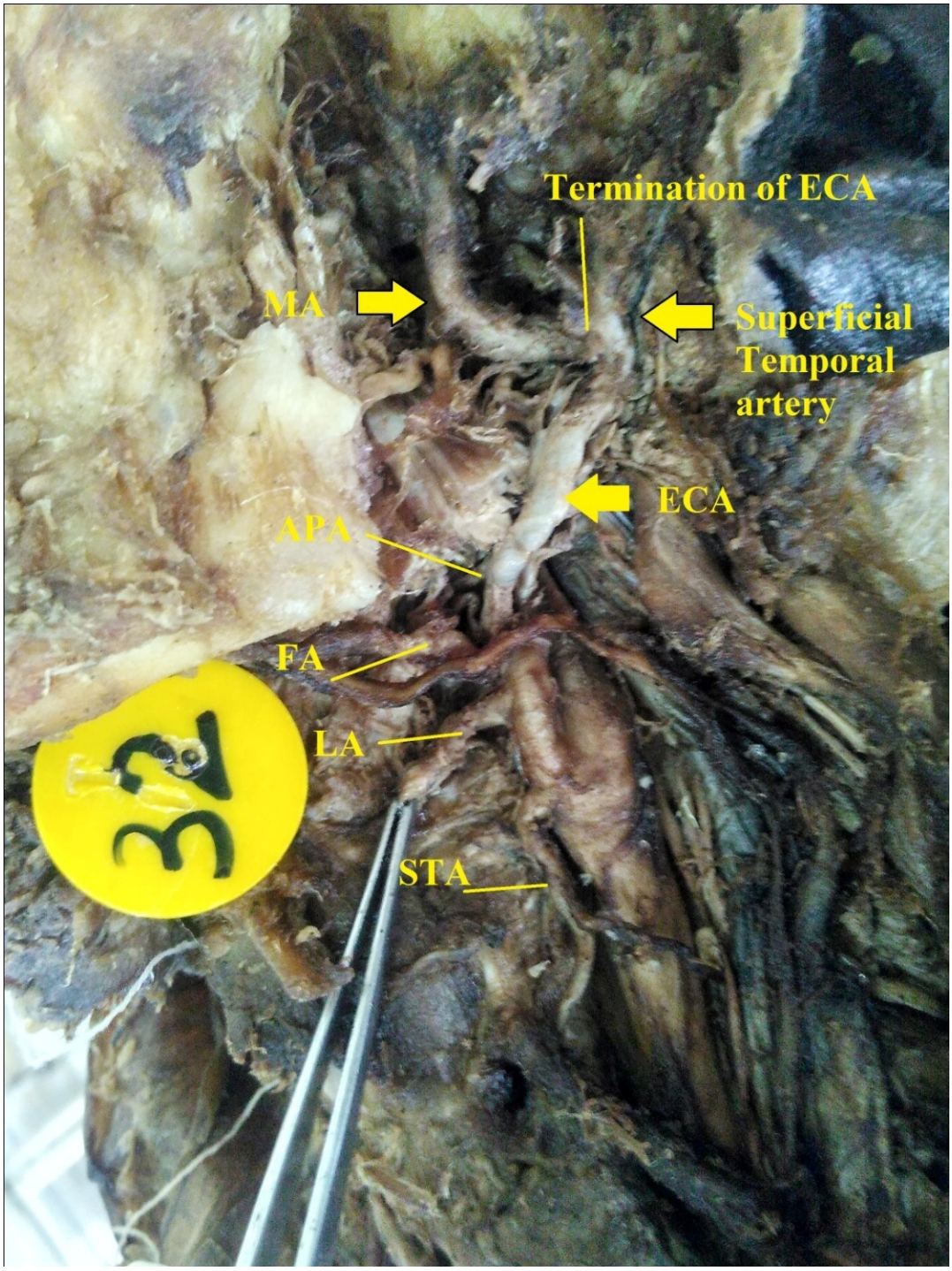


Table: 17

ORIGINOF LEVEL OF SUPPERICIAL TEMPORAL ARTERY	FREQUENCY	PERCENTAGE
At the level of the neck of mandible	50	100%
Others	NIL	_

In the current study the Superficial temporal artery was arising as separate branch in all the specimens, at the level of termination of the External carotid artery. (Fig- 25)

DISCUSSION

Sir William Osler has quoted that “VARIABILITY IS THE LAW OF LIFE”.

As per his quote, variations do occur in the human body. The motive of anatomical studies usually lies in the identification, documentation and correlation of the variations with the developmental reasons and the clinical impacts of them.

Also it becomes clear that the diagnostic accuracy, treatment design and the success of operative intervention is dependent on the precise knowledge of anatomy.

The frequency of variations, in the origin of ECA and its each single branch is highlighted in this study.

The common carotid artery usually bifurcates into external carotid artery and internal carotid artery at the upper border of C4 vertebra, that is at the level of the upper border of lamina of thyroid cartilage. It may also bifurcate at a higher level near the tip of the greater cornu of hyoid bone (C3 vertebra)[16].

The External carotid artery after it commences, lies anteromedial to the Internal carotid artery within the carotid triangle. It ascends and courses deep to the posterior belly of digastric muscle, then pierces the parotid fascia. This

way it enters into the parotid gland and within the gland it divides into maxillary and superficial temporal artery, at the level behind the neck of the mandible[16].

Before the ECA terminates, it gives six branches, three from front, that is the superior thyroid artery, lingual artery, facial artery, one from the medial aspect which is the ascending pharyngeal artery and two from behind, being the occipital and posterior auricular artery[l6].

This part of the study material deals with the analysis and comparison of various older studies with the present study, with regard to all the paramaters which is taken in the current study.

I) ORIGIN OF EXTERNAL CAROTID ARTERY - BIFURCATION OF COMMON CAROTID ARTERY (CB)

The common carotid bifurcation (CB), into ECA and ICA is an anatomically and surgically important landmark, since it is involved in a variety of physiological and pathological process. Hayashi[24] (2005) and Anu[8] (2007), have used the cervical vertebraes, as landmark to determine the CB.

Heltzel[64] (2015), had located the level of carotid bifurcation in relation to the midpoint between the mastoid process and the suprasternal notch.

The studies by Ozgur[54] (2008), Al-Rafiah[4] (2011), and the current study, have considered the thyroid cartilage and hyoid bone as the landmarks of CB.

Standring Gray[72] states that CCA bifurcates into ECA and ICA, at the level of upper border of thyroid cartilage normally.

Lucev[41] (2000), has given his incidence to be 50 %, Ozgur[54] (2008) having his incidence as 27.5%, Al-Rafiah[4] (2011) with 48.3% incidence and Blanca[13] (2015) to have 63.5%, where the CB and the origin of ECA was at upper border of thyroid cartilage level.

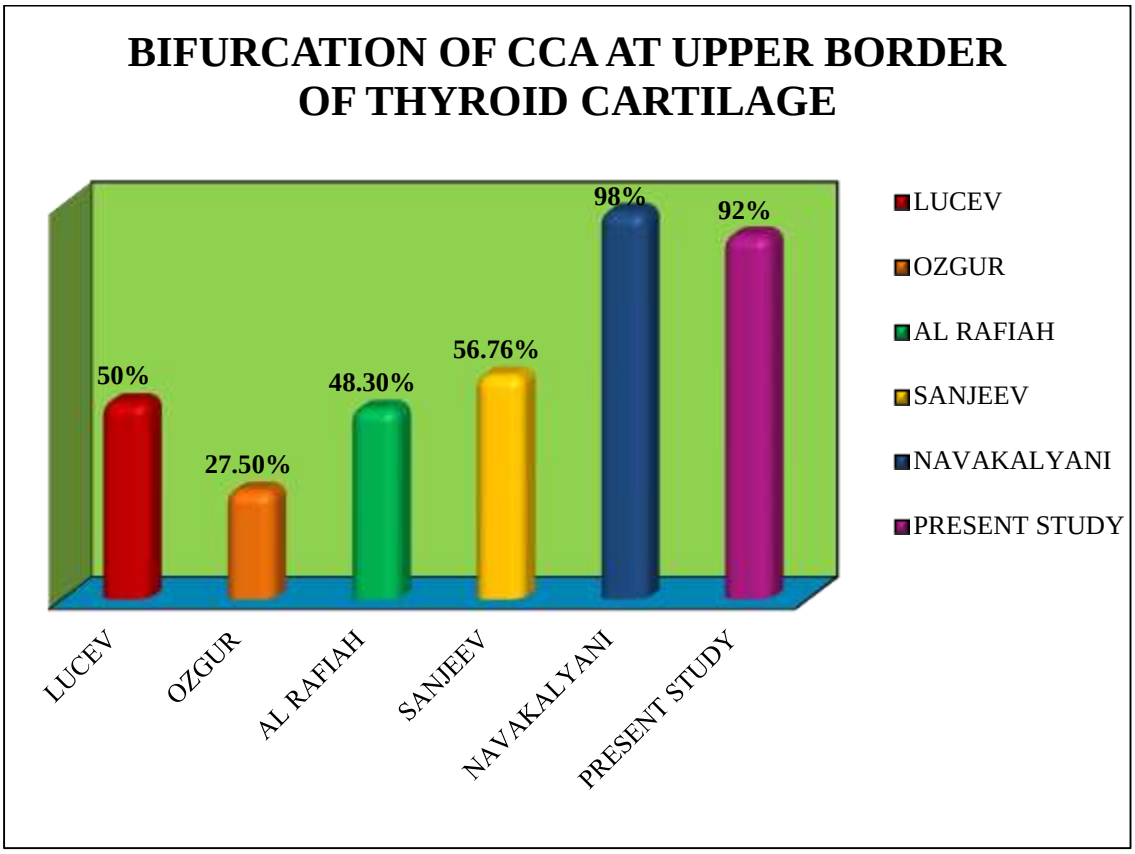
Sanjeev[63] (2010) has reported only 56.76% of incidence, whereas Himabindu[26] (2012) tells that all the specimens in his study showed the origin of ECA at thyroid cartilage, in its upper border level.

Navakalyani[52](2016) in her study on 60 dead fetuses, have observed 98% specimens with this usual origin of ECA.

An extremely rare case report was registered by Murono[51](2009), where he noted a non- bifurcating CCA in a patient with laryngeal cancer, on his right side. The CCA was continuing as ICA with the usual branches of ECA arising from Internal carotid artery. On the other side, the common carotid bifurcation was found to be normal.

The current study showed 92% of cases having normal origin of ECA, which correlates with Navakalyani[52] study. The bifurcation at higher levels varied in these studies.

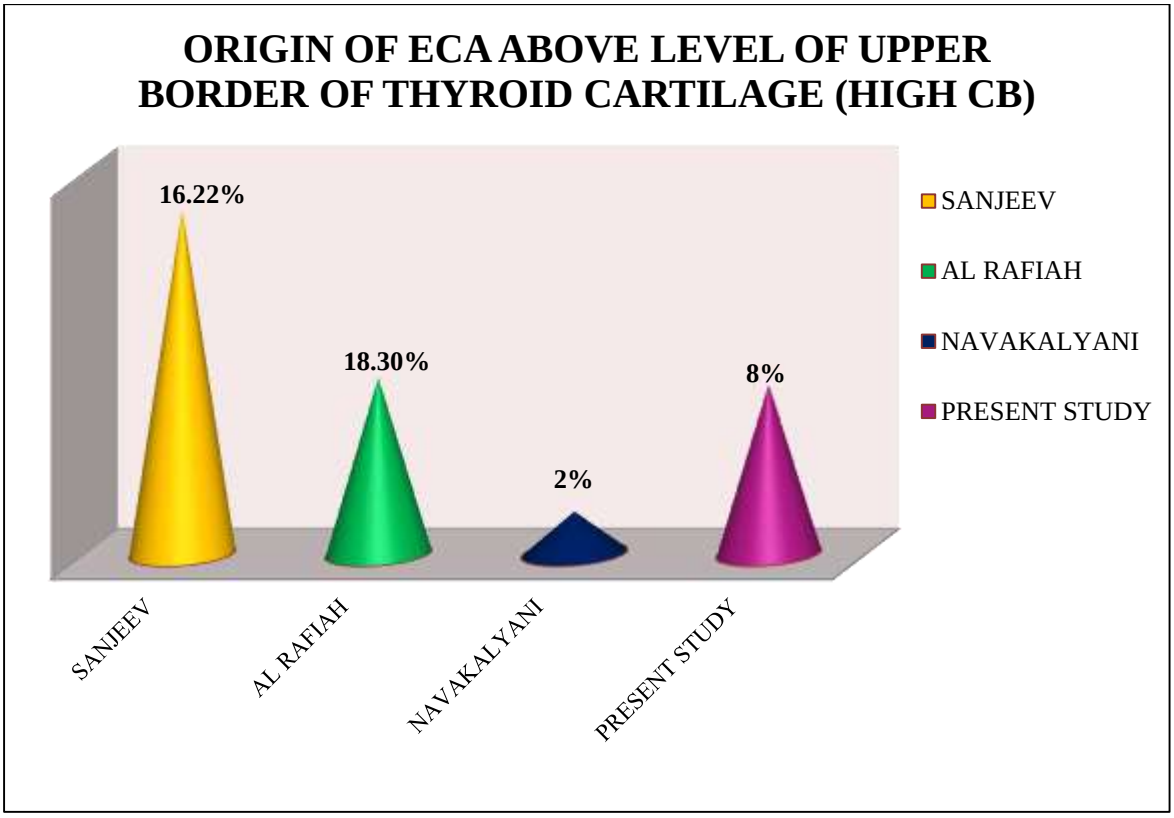
Chart:8



Al Rafiah[4] (2011) and Lucev[41] (2000) showed 25% cases of CB, at hyoid bone level but Blanca[13](2015) has given 36.85% incidence of this kind. Sanjeev[63] (2010) has noted 16.22% cases and Al Rafiah[4] (2011) with18.3% incidence, showing origin of ECA just above the superior border of thyroid cartilage. Ramakrishna[59] (2012), in his case report, had mentioned about a relatively high bifurcation of common carotid artery, which was above the posterior belly of digastric muscle.

Navakalyani[52] (2016) with 2% incidence is closely correlating with my study having 8% incidence, in the above regard.

Chart: 9



II) RELATION BETWEEN ECA AND ICA IN THE CAROTID TRIANGLE

Standring Gray[72] states the relation of ECA to be commonly in anteromedial position to ICA. Smith[71] (1979), stated 8% cases showing anterolateral position of ECA.

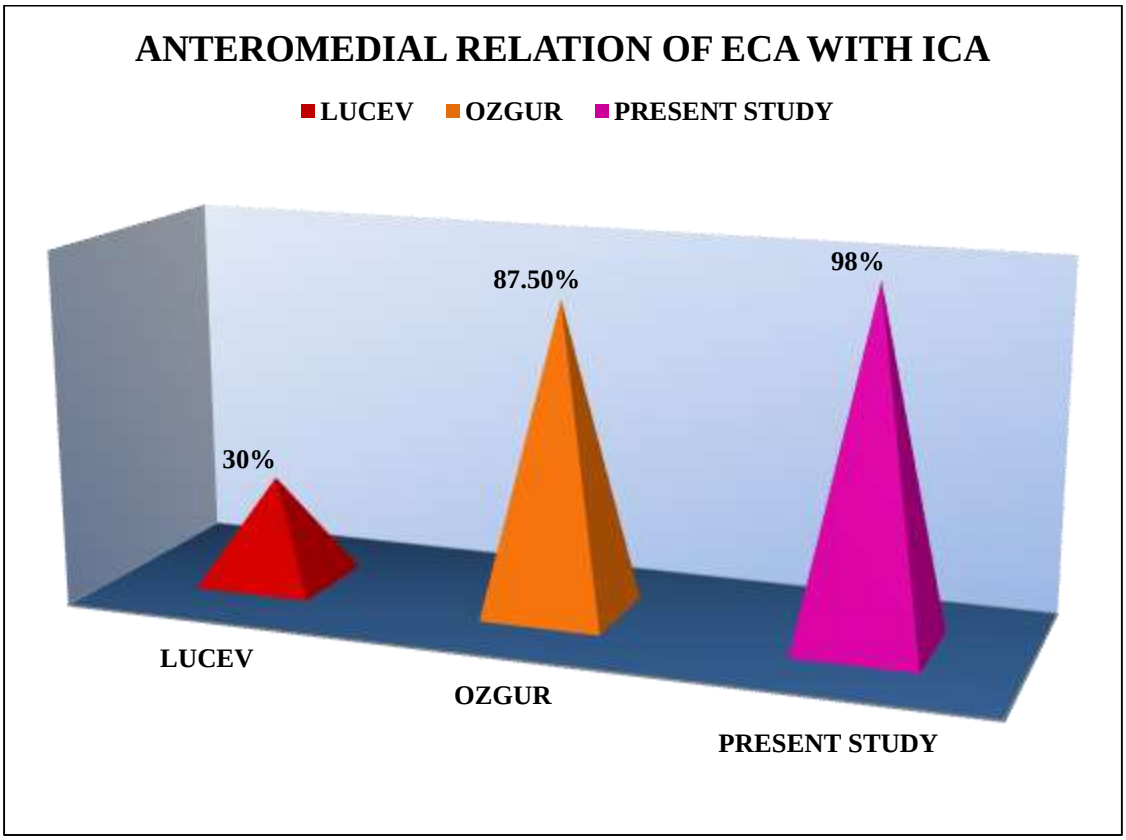
Lucev[41](2000), in his study on 40 carotid arterial system, mentions his observations on the relation of ECA with ICA in such a way that, in 10% specimens the ECA was lateral to ICA, but one case with 2.5% incidence were showing the anterolateral relation of ECA with ICA. In his study only 30% cases showed the usual anteromedial relation of ECA.

Ozgur's[54] (2008) report on his study states about the 87.5% incidence of the usual relation of external carotid artery. In the present study, we observed 98% specimens with the anteromedial relationship of ECA with ICA, closely correlating with the Ozgur's[54] study.

Bailey[11](2007), when dissecting 4 cadavers found 2 cases showing lateral relation of ECA with ICA. Also he mentions that the incidence of lateral relationship of ECA with ICA, varies from 4 – 12.3% in some of the older studies.

Al Rafiah[4](2011) had mentioned about the 1.7% incidence of the lateral position of ECA with ICA, in the carotid triangle.

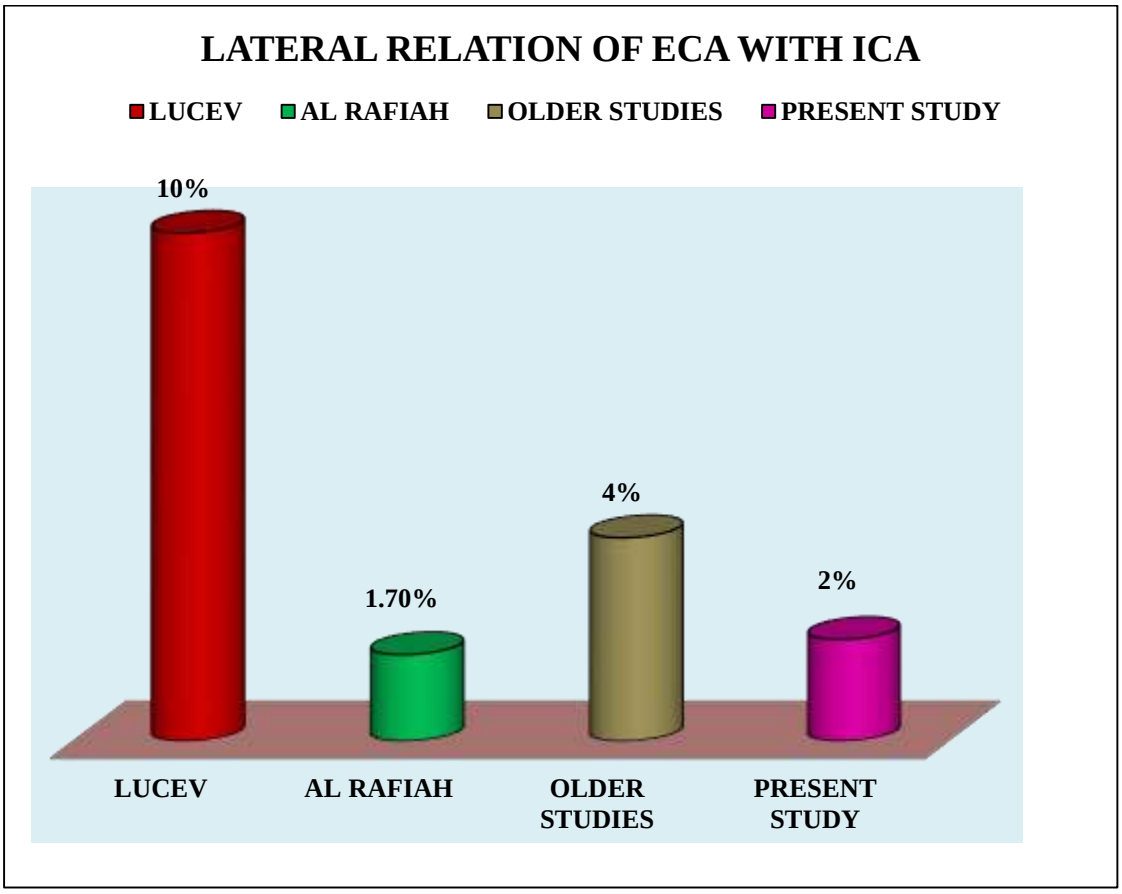
Chart:10



Annette[34] (2015), has reported a case with lateralization of ECA, who also refers about a 4% incidence in some older study. Also Sujatha[73] (2012), had mentioned about a case with antero-lateral relation of External carotid artery with Internal carotid artery. In this current study, one case was noted with lateral position of ECA with ICA and the incidence was 2%. The branches emerging from the external carotid artery were coursing superficial to the internal carotid artery.

The present study is correlating with Al Rafiah's[4] study with regard to the transposition of external carotid artery (Chart: 11).

Chart:11



III) ORIGIN OF SUPERIOR THYROID ARTERY

The superior thyroid artery, is the first anterior branch of external carotid artery, but it can arise from the CB or from the common carotid artery[72]. Lucev[41] (2000) and Zumre[84] (2005) had reported the origin of STA from ECA in 30% and 25% of the cases. Ozgur[54] (2008) gave consistent results with 25% of cases, and that of Hayashi[24] (2005) with high incidence of about 81%.

Sanjeev[63] (2010) has observed 64.86% of incidence, Joao[47](2012) has 51.2%, Navakalyani[52](2016) with 88% incidences in this aspect. Abhijeet[1] (2014) in his work on STA, has shown the incidences of the origin of superior thyroid artery from ECA to be 66.67%. The present study has revealed 58% incidence of STA to arise from ECA, correlating with Joao[47] (2012). (Chart: 12)

The emergence of STA from CB as shown by Lucev[4] [1](2000) was 22.5%. Whereas studies by Joao[47] (2012) and Abijeet[1](2014) were 45.3% and 31.81% respectively. Zumre's[8] [4](2005) report is relatively high with 70% incidence in this aspect. The current study revealed 26% of incidence in this respect, that correlates with Lucev[41] (2000). (Chart: 12)

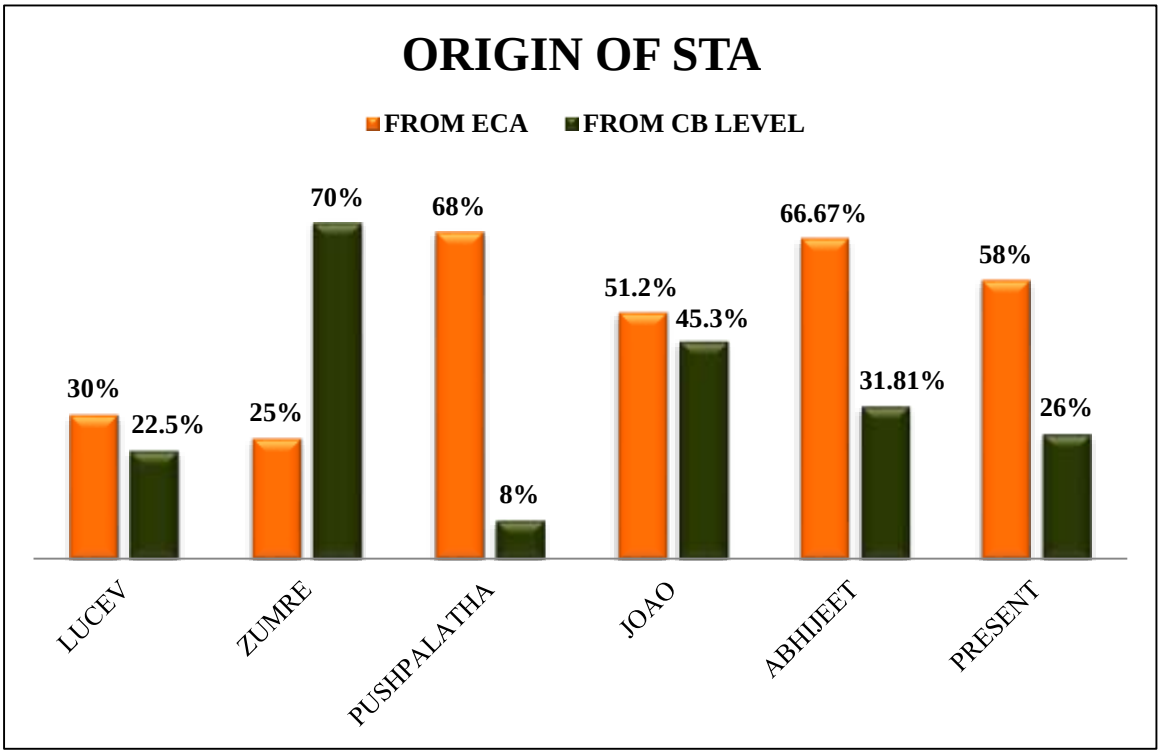
In the present study, STA was originating from CCA less frequently with the prevalence of 12%. The study done by Joao[47] (2012) had reported 3.3% cases of this type. Sanjeev[63] (2010) observed more such variations in his study i.e around 35.14% and Anjalee[7] (2016) has noted 11.66% cases. Lucev[41] (2000), Ozgur[54] (2008) and Zumre[84](2005) had given 47.5%, 35% and 5% incidences respectively.

Pushpalatha[56] (2015) in her study has observed the origin of STA, as 68% from ECA, 24% from CCA and 8% from CB. The present study with

respect to the emergence of STA from CCA, correlates with the study by Anjalee[7] (2016). (Chart: 13)

Common origin of STA with Lingual artery as thyrolingual trunk (TL), was 4% in my study. Sanjeev[63] (2010) showing 2.7%, Anjalee[7] (2016) with 8.33%, Joao[47] (2012) having 2.8%, Navakalyani[52](2016) with 2% incidences,Abhijeet[1] with 1.51% and older studies of Ozgur[54](2008) and Zumre[84](2005) with 2.5% incidences of TL trunk closely correlates with the finding of current study. (Chart: 13)

Chart:12

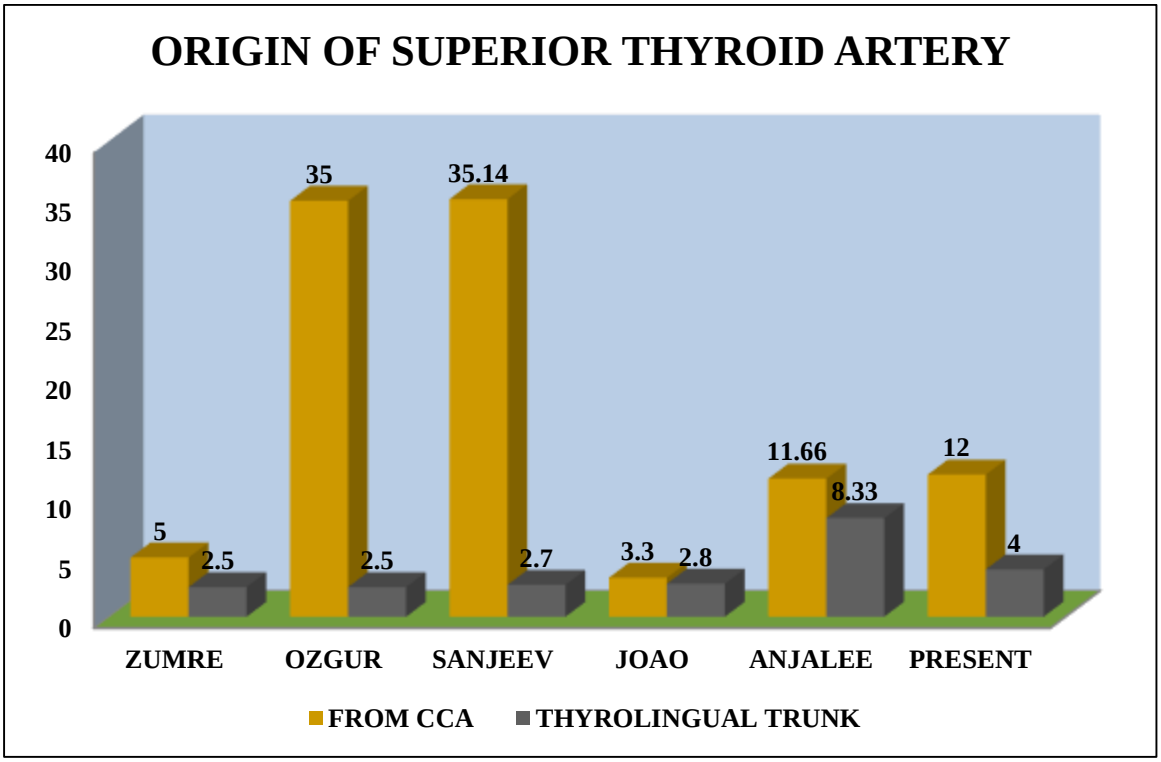


Another possibility of emergence of Superior thyroid artery as common thyrolinguofacial trunk has also been observed in various studies.

Ragu sugavasi[58] (2012), had mentioned about a case with the origin of LA, FA, STA as common throlinguofacial trunk, which was emerging below the level of common carotid bifurcation.

Other studies with this observation is been discussed subsequently. The present study has not observed such variations in any of the specimens.

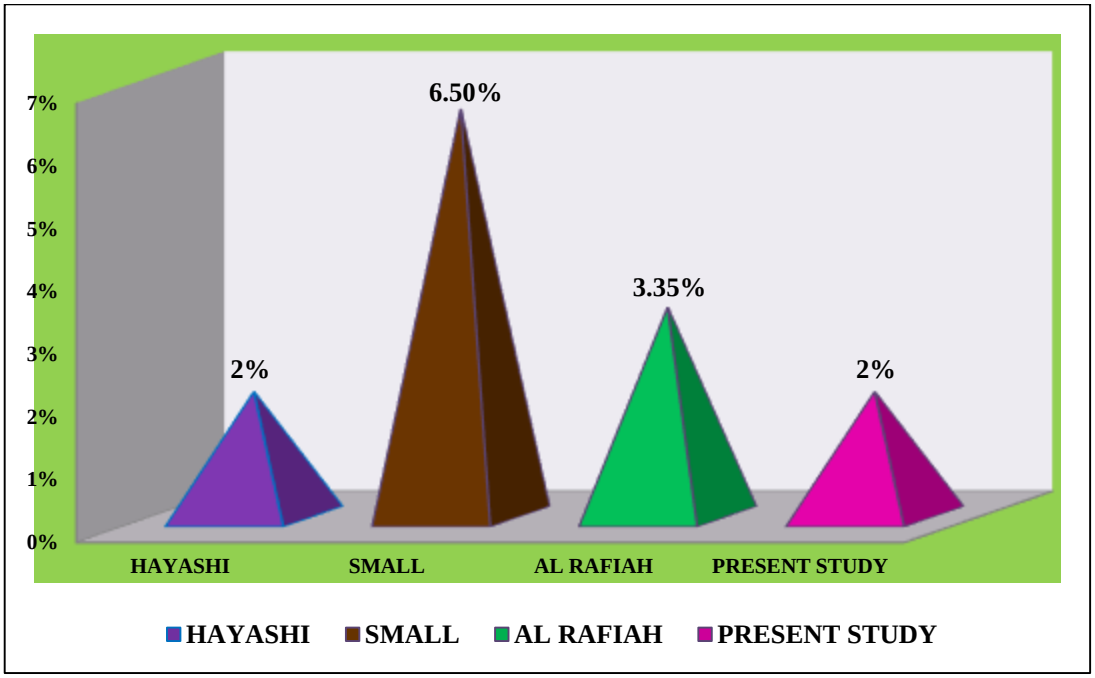
Chart:13



IV) ORIGIN OF ASCENDING PHARYNGEAL ARTERY (APA)

The ascending pharyngeal artery frequently originates from the medial aspect of the external carotid artery near the bifurcation of the CCA[72].

Chart:14



Hayashi[24](2005), had reported 2% cases with APA arising from CB. Another 2% was from ICA. Zumre[84](2005) had given prevalence of the later to be 2.5%. Both their studies were showing consistent results.

According to the radiographic study by Small[69] (2014), APA originated from CB in 6.5% cases, which is relatively a higher incidence compared to the other studies. Al Rafiah[4](2011) says, 95% of his cases were showing the origin of APA from ECA and only 1.7% cases showed its origin to be from ICA, whereas remaining 3.35% from CB (chart: 14). Blanca's[13] (2015) observations were 2.6%, with its origin from ICA.

Himabindu[26] (2012), noted 2 cases with higher origin of ascending pharyngeal artery, in his study with 20 cadavers. Anjalee's[7] (2016) observations were 8.34% of higher origin of APA, while she had noted one case with its origin from CB.

The variations in the origin of APA from CB, as observed in the present study is 2% and that from medial aspect of ECA was 98% , which correlates with most of the previous studies and well with Hayashi's[24] study.

V) ORIGIN OF LINGUAL ARTERY (LA)

Selective and superselective chemoembolization of laryngeal and hypopharyngeal tumours, by catheterization of LA and STA which were the usual feeding vessels, demands caution, expertise and knowledge of their anatomic variability, because any existence of common trunks if unrecognized, will cause diffusion of drugs in undesired sites.

The anomalous common origin of linguofacial trunks as reported in older studies, of that of Hayashi[24] (2005), Lucev[41] (2000), Zumre[84] (2005),was 20% in all. Recent researches of Sanjeev[63] (2010), observed linguofacial trunks in18.92% cases, Himabindu[26] (2012) in 10-20%, Vishnu[82] (2014) in 13.3%, Anjalee[7](2016) in 58.33%, Julius[53] (2015) in 44.7% cases, Anuradha[9](2017) in 10% and Joao[47](2012) with 19.4% of incidences. The present study had observed 22% specimens with linguofacial trunks, correlating with the studies by Sanjeev[63]and Joao[47] (Table: 18).

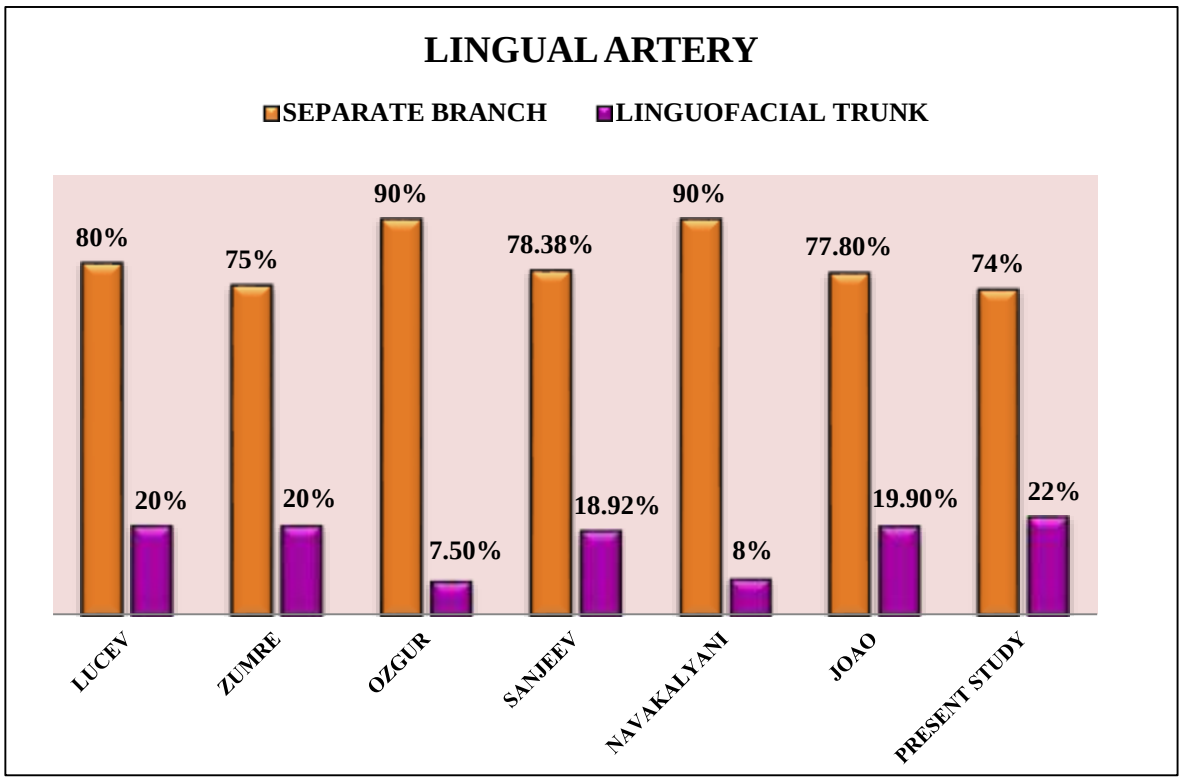
Table: 18

AUTHORS	SEPARATE BRANCH (LA)	LINGUOFACIAL TRUNK	THYROLINGUAL TRUNK
Lucev(2000)	80%	20%	_
Zumre (2005)	75%	20%	2.5%
Ozgur (2008)	90%	7.5%	2.5%
Sanjeev(2010)	78.38%	18.92%	2.7%
Joao (2012)	77.8%	19.9%	2.8%
Himabindu(2012)	90%	10%	_
Vishnu (2014)	85.4%	11.3%	_
Navakalyani (2016)	90%	8%	2%
Anjalee (2016)	32.5%	58.33%	8.33%
Anuradha(2017)	90%	10%	_
Present study	74%	22%	4%

Studies of Sanjeev[63] (2010), Joao[47] (2012), Navakalyani[52] (2016), showed LA arising as separate branch in 78.38%, 77.8%, 90% specimens respectively. The current study had 74% cases with LA as separate branches, which is closely correlating with their studies. Incidence of thyrolingual trunks as given by Ozgur[54] (2008) and Zumre[84] (2005) is 2.5%, while that of Sanjeev[63] (2010), Al Rafiah[4](2011), Navakalyani[52](2016), were 2.7%, 1.7% and 2% respectively.

In this study 4% cases were with thyrolingual trunks. Zumre[84](2005) noticed 2.5%, Vishnu[82](2014) observed 3.3% cases and Anjalee[7](2016) noticed 0.83% of thyrolinguofacial trunks.

Chart:15



VI) ORIGIN OF FACIAL ARTERY (FA)

The facial artery normally arises from the ECA, just above the LA, at the level of greater cornu of hyoid bone, in the carotid triangle. The common reported variation of the FA is its origin as linguofacial trunk, which was around 22% in the present study, has been discussed as in (Table: 18) . Asha[10](2016), in her work on 50 cases, had reported 4% of linguofacial trunks, which seems to be less compared to the present and other older studies.

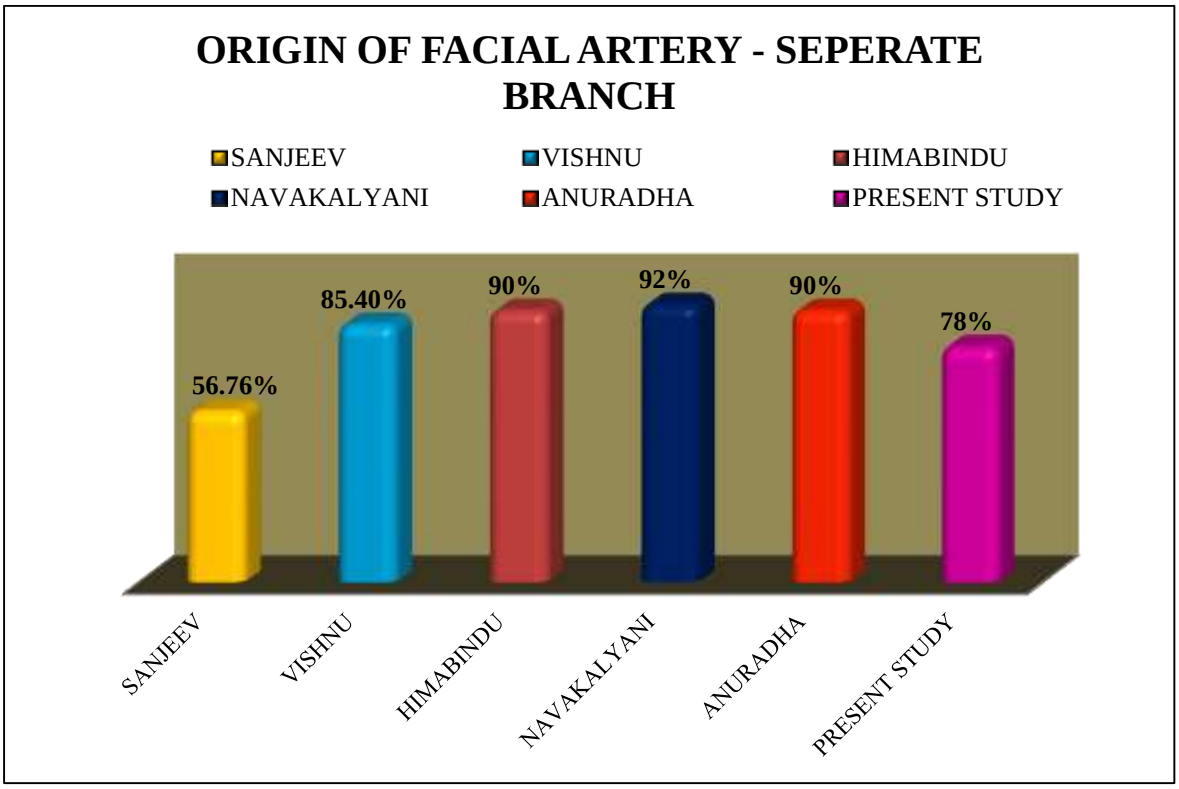
Other variations reported in literature is the presence of thyrolinguofacial trunk as in the studies of Zumre[84] (2005) with prevalence of 2.5%, Al Rafiah[4] (2011) with 1.7%, Vishnu[82](2014) having 3.3% and Anjalee[7](2016) with 0.83%. The present study showed no such variation, except for the linguofacial trunks, correlating with Himabindu[26] (2012) and Navakalyani[52] (2016).

Sanjeev[63] (2010) showed 56.76% cases with FA arising as separate branch. Vishnu[82] (2014) had an incidence of 85.4%, while Himabindu[26] observed 90% incidence with regard to the origin of facial artery as a single branch from external carotid artery.

Studies of Navakalyani[52] with 92% incidences and Anuradha[9](2017) also with 90%, has reported on FA originating as separate branches.

The current study with 78% incidence is closely correlating with Vishnu[82] (2014) (Chart: 16).

Chart:16



VII) ORIGIN OF OCCIPITAL ARTERY (OA)

Occipital artery usually branches off from the posterior wall of the ECA at the same level as that of facial artery[48]. Heltzel[64] (2015), had said in 55% of his cases, OA emerged below the level of FA.

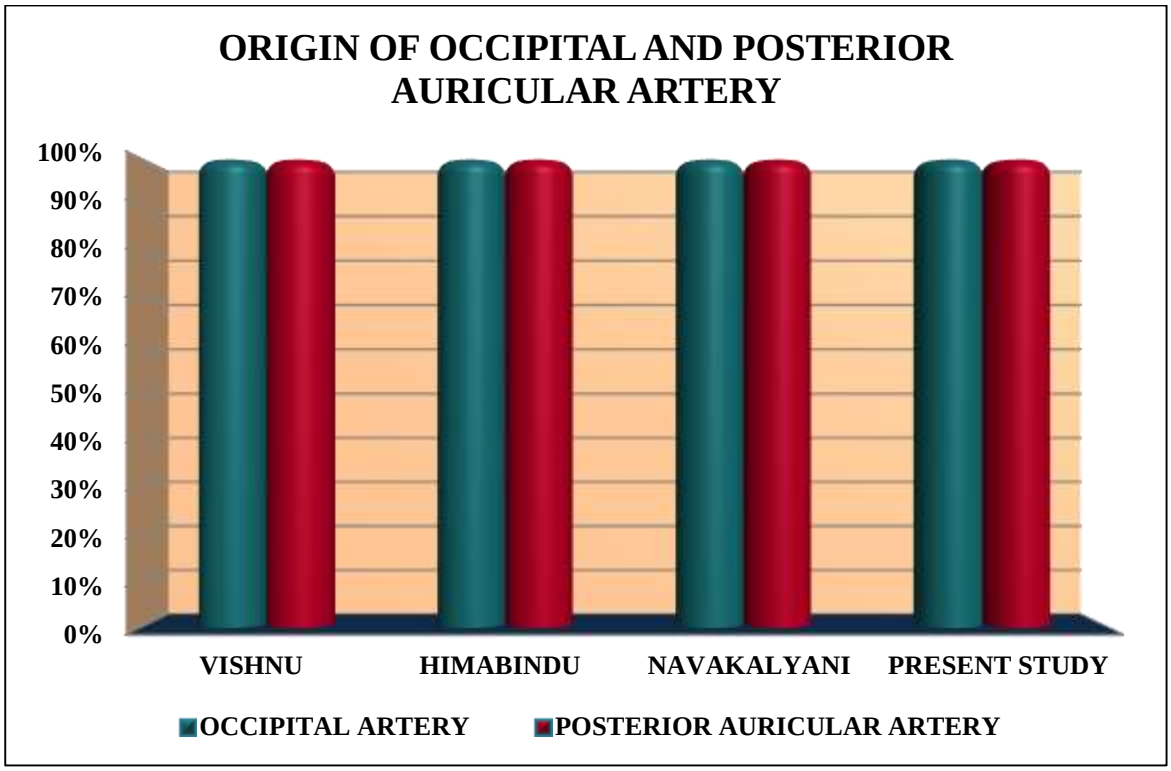
This present study showed only 6% cases with OA arising below level of FA. Studies of Navakalyani[52] (2016), Himabindu[26] (2012) showed none. Zumre[84] (2005) observed 12.5% cases with occipito-auricular trunk, when he studied human fetuses, whereas Sanjeev[63] (2010), studied that 2.70% specimens showed occipito-auricular trunk. Al Rafiah[4] (2011) had given 18.3% cases, and Anjalee[7] with 5% of such variation.

Studies of Himabindu[26] (2012), Vishnu[82] (2014), Navakalyani[52](2016) and the current study showed none of these variations, where OA was emerging as separate branches, thereby this study correlates with them (Chart: 17).

VIII) ORIGIN OF POSTERIOR AURICULAR ARTERY (PAA)

The uncommon variation noted in case of posterior auricular artery is the presence of occipitoauricular trunk[24]. Mostly PAA emerges as a separate branch from ECA from its posterior side.

Chart:17



Studies by Al Rafiah[4] (2011), Sanjeev[63](2010), Anjalee[7](2016) had reported the incidence of PAA arising as a separate branch in 81.7%, 73%, and 95% cases respectively. Ramesh[61] (2011), noted a rare variation that all the branches including posterior auricular artery, except STA emerged from a common point of External carotid artery.

The present study correlates with studies by Himabindu[26] (2012), Vishnu[82](2014) and Navakalyani[52](2016), who have all observed PAA emerging as separate branch from all the cadavers.

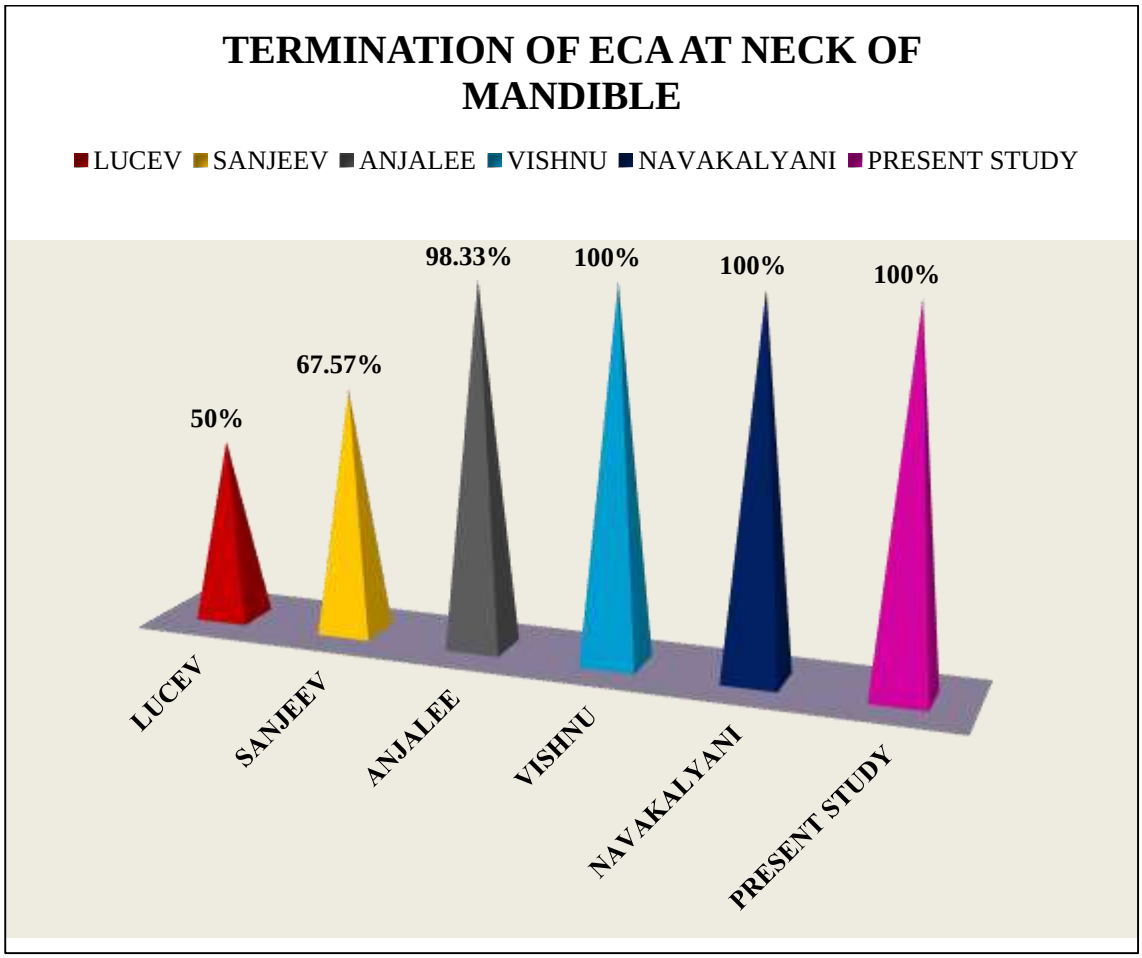
IX) TERMINATION OF EXTERNAL CAROTID ARTERY

The external carotid artery generally terminates into maxillary artery (MA) and superficial temporal artery at the level of the neck of the mandible[72]. Shakuntala [66](2014) had reported a case with trifurcation of ECA as Superficial temporal artery, Maxillary artery & Middle meningeal artery.

Julius Ogengo[53] (2015), says that termination of ECA into trifurcation were found to be more common than its bifurcation with 26.8% and 17.9% incidences respectively. Himabindu[26] (2012), Vishnu[82](2014), and Navakalyani[52](2016) reported that all their cadavers showed the usual bifurcation pattern of termination, all occurring at the level of the mandible. While Anjalee[7](2016), had given 1.67% incidence of termination of ECA into trifurcation in her study, where PAA, MA and APA had contributed for the termination and the normal level of termination of ECA in her study seemed to have 98.33% incidence.

Lucev[41](2000), reported 50% cases with usual level of termination and 37.5% cases with higher level of termination. Sanjeev[63] (2010), stated an incidence of 67.57% regarding the termination at the level of neck of the mandible and an incidence of 32.43%, where the termination occurred at higher level.

Chart: 18

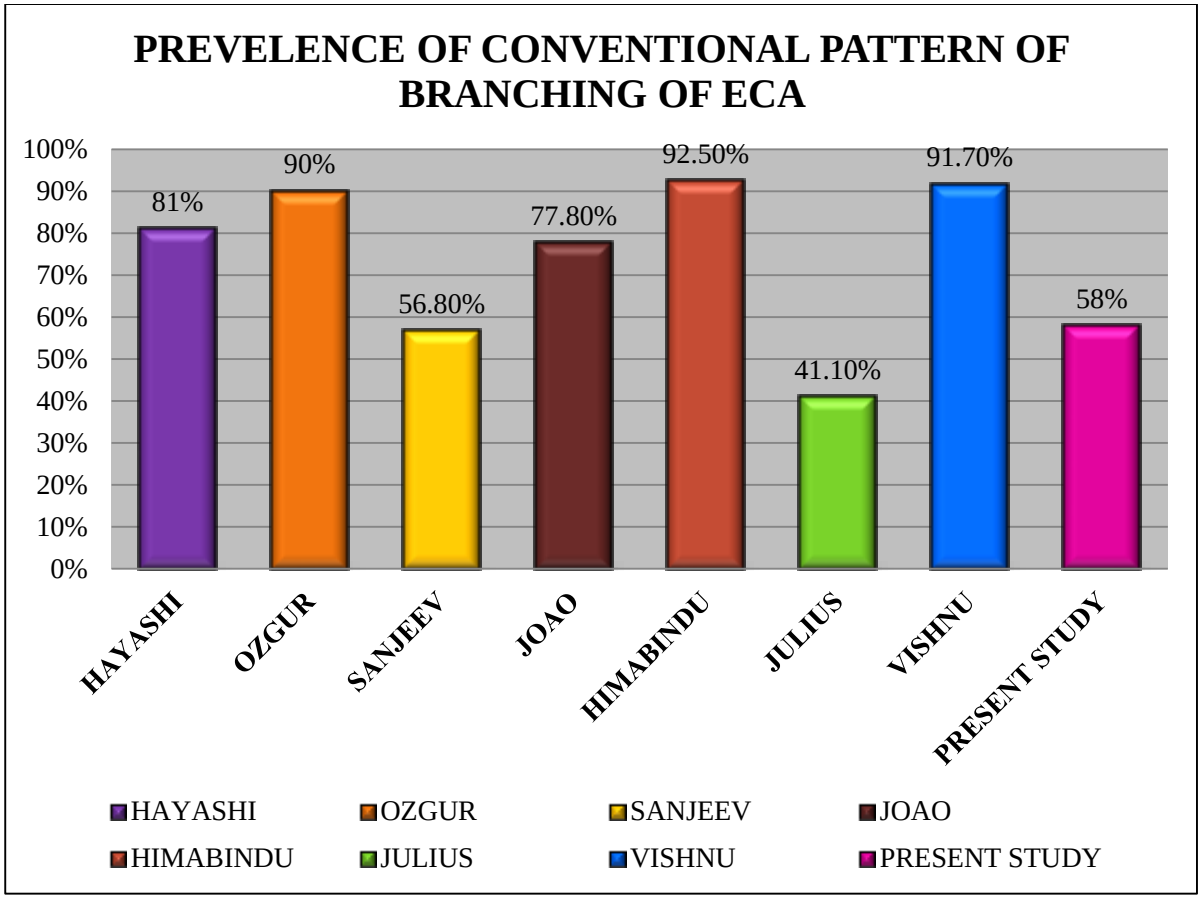


Surekha[75] (2015), noted a low level of termination of External carotid artery into Maxillary and Superficial temporal artery, which occurred deep to the posterior belly of digastrics muscle. This is an extremely rare kind of variation noted ever.

The current study, showed the conventional pattern of termination in all specimens, all at the level of the neck of the mandible, thereby correlating with that of Himabindu[26], Vishnu[82], Navakalyani[52] and closely correlating with that of Anjalee[7].

X) PREVELENCE OF CONVENTIONAL ORIGIN AND BRANCHING PATTERN OF ECA IN VARIOUS STUDIES

Chart: 19



The datas on the type of the branching pattern and the frequencies with which the vascular variations of ECA occur, may be different in various populations of the world. Moreover the patterns of the branching of ECA may also show ethnic variations. When we compare the conventional branching pattern of ECA it was found to be very less prevalent in Kenyan population.

Table: 19

CONVENTIONAL BRANCHING PATTERN IN ECA IN VARIOUS POPULATIONS.

AUTHOR	SAMPLE SIZE	PREVELENCE
Hayashi (2005)	98	81%
Ozgur (2008)	40	90%
Sanjeev(2010)	37	56.8%
Joao (2012)	36	77.8%
Himabindu (2012)	40	92.5%
Julius ogengo(2013)	224	41.1%
Vishnu (2014)	60	91.7%
Present study	50	58%

The prevalence observed in case of Japanese (Hayashi[24]), Turkish (Ozgur[54]), Brazilian (Joao[47]) populations were high.

Also, in India, the prevalence was varied in various populations as reported in the studies of Sanjeev[63], Himabindu[26], Vishnu[82] and the Present study, thus showing ethnic variations. The current study correlates with the study of Sanjeev[63].(Chart: 19)

SUMMARY AND CONCLUSION

The current study was done to study the origin and branching pattern of the external carotid artery in 50 hemi-necks from 25 cadavers (25 right and 25 left sides of the necks), irrespective of the age and sex, by gross dissection method. This study has observed the origin, the relation with the internal carotid artery, the level of origin of various branches, of the external carotid artery and their variations. The observations that had been recorded were summarized, analysed and were correlated with the data of the previous studies.

- **External carotid artery origin**
  - 92% cases revealed the origin of external carotid artery from the bifurcation of common carotid artery at the level of upper border of thyroid cartilage.
  - In 8% of cases, the origin was above the thyroid cartilage, showing high bifurcation of common carotid artery.
- **Relation of External carotid artery with Internal carotid artery in the carotid triangle.**
  - In 98% of specimens, the external carotid artery was anteromedial in position to the internal carotid artery.
  - 2% of specimen showed the lateral relation of external carotid artery to that of internal carotid artery.

❖ **Origin of Superior thyroid artery**

- In 58% cases, the superior thyroid artery emerged from the external carotid artery, above the bifurcation of common carotid artery.
- 26% cases, revealed the origin of superior thyroid artery from level of carotid bifurcation.
- In 12% cases, its origin was from the common carotid artery.
- Another 4% cases revealed the existence of thyrolingual trunk, where the superior thyroid artery shared common trunk with lingual artery.

❖ **Origin of Ascending pharyngeal artery**

- 98% cases had revealed the emergence of ascending pharyngeal artery from the medial aspect of external carotid artery.
- Another 2% of specimen were observed to have it originating from the common carotid arterial bifurcation.

❖ **Origin of Lingual artery**

- In 74% of cases, the lingual artery was found to be arising as separate branch.
- In 22% cases, it was sharing a common trunk with facial artery, as linguofacial trunk, which was the most commonest variation noted in this study.
- In 4% cases, it was arising as thyrolingual trunk and then separating as lingual artery.

❖ **Origin of Facial artery**

- 78% specimens revealed facial artery arising as a separate branches.
- Rest of 22% of specimens showed linguofacial trunks, with facial artery arising in common with the lingual artery.

❖ **Origin of Occipital artery**

- In 96% cases, the occipital artery emerged opposite to the level of facial artery.
- The rest 4% cases were showing the artery, arising opposite to the lingual artery.

❖ **Origin of Posterior auricular artery**

- All the specimens (100%) revealed the posterior auricular artery arising from the posterior aspect of external carotid artery, as separate branch.

❖ **Termination of External carotid artery**

- In all the cases (100%), the termination of external carotid artery was at the level of the neck of the mandible. The termination occurred as bifurcation into maxillary artery and superficial temporal artery, within the parotid gland.

Anatomic characteristics of interest in this study is the high bifurcation of common carotid artery with high origin of external carotid artery and the anatomic variations of its branching pattern, which deals with many

pathological mechanisms and their surgical management including carotid atheromatosis and carotid endarterectomy, surgical oncology of head and neck tumors. In the treatment of head and neck tumours, the existence of common trunks might decrease the vessel diameter, where the feeding artery might be inadequate for catheterization leading to catheterization accidents like rupture of vessels or will lead to infusion of chemotherapeutic agents to undesired sites.

The transposition of external carotid artery and internal carotid artery, will have a potentially limiting access to internal carotid artery during carotid endarterectomy and also the risk of bleeding during pharyngeal surgeries is increased due to the medially displaced internal carotid artery.

Knowledge of the surgical anatomy of superior thyroid artery ensures to maintain a bloodless surgical field during radical neck dissection. Also superior thyroid artery takes part in the collateral circulation between internal and external carotid artery, which becomes important during unilateral occlusion of common carotid artery.

The present study gives information about the prevalence of common trunks like linguofacial trunks, thyrolingual trunks in the anterior triangle of the neck, which helps the surgeons to take care during intra oral biopsies, extractions and other dental implant procedures.

The elevation of various cutaneous and myocutaneous flaps for plastic and reconstructive surgeries of the head, neck and face, depends on the

external carotid artery for their blood supply. Moreover, in preoperative selective arterial angiograms done to know the vascularity of the tumours of the head, neck and face, and in Surgeries like thyroidectomy, laryngectomy, faciomaxillary surgeries, tonsillectomy and glossectomy, a surgeon or a radiologist should know of the variations of its branching pattern.

Hence we conclude that, this study was undergone, to recognize the likelihood of the prevalence of conventional branching pattern of external carotid artery and the incidence of variations in them, which helps in reducing the morbidity associated with surgical and radiological procedures of the neck.

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ABBREVIATION

ECA – EXTERNAL CAROTID ARTERY

CCA – COMMON CAROTID ARTERY

ICA – INTERNAL CAROTID ARTERY

CB – CAROTID BIURCATION

TC – THYROID CARTILAGE

STA – SUPERIOR THYROID ARTERY

APA – ASCENDING PHARYNGEAL ARTERY

LA – LINGUAL ARTERY

FA – FACIAL ARTERY

OA – OCCIPITAL ARTERY

PAA – POSTERIOR AURICULAR ARTERY

MA – MAXILLARY ARTERY

MASTER CHART																
		ORIGIN OF ECA		RELATION OF ECA WITH ICA		ORIGIN OF STA				ORIGIN OF APA			ORIGIN OF LA			
						SEPARATE BRANCH			TL TRUNK	SEPARATE BRANCH			SEPARATE BRANCH		COMMON TRUNK	
SP. NO	SIDE	UPPER BORDER OF THYROID CARTILAGE	ABOVE LEVEL OF THYROID CARTILAGE	ANTERO-MEDIAL	LATERAL	FROM ECA, above CB	FROM ECA at CB	FROM CCA	TL TRUNK	FROM ECA	FROM CB	COMMON TRUNK	AT GREATER CORNU LEVEL	BELOW GREATER CORNU LEVEL	LINGUO-FACIAL TRUNK	TL TRUNK
1	LEFT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
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3	RIGHT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
4	LEFT	-	+	+	-	-	-	+	-	+	-	-	+	-	-	-
5	RIGHT	-	+	+	-	-	-	+	-	+	-	-	+	-	-	-
6	LEFT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
7	RIGHT	+	-	+	-	-	+	-	-	-	+	-	+	-	-	-
8	LEFT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
9	RIGHT	+	-	+	-	+	-	-	-	+	-	-	-	-	+	-
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14	RIGHT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
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16	RIGHT	-	+	+	-	-	-	+	-	+	-	-	+	-	-	-
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23	RIGHT	+	-	+	-	-	+	-	-	+	-	-	+	-	-	-
24	LEFT	+	-	+	-	-	+	-	-	+	-	-	-	-	+	-
25	RIGHT	+	-	-	+	-	+	-	-	+	-	-	+	-	-	-
26	LEFT	+	-	+	-	-	+	-	-	+	-	-	+	-	-	-
27	RIGHT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
28	LEFT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
29	RIGHT	+	-	+	-	+	-	-	-	+	-	-	-	+	-	-
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		MASTER CHART									
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SP. NO	SIDE	SEPARATE BRANCH	TLF TRUNK	LINGUO FACIAL TRUNK	FACIAL ARTERY LEVEL(OR) LEVEL OF GREATER CORNU	BELOW FACIAL ARTERY LEVEL	SEPARATE BRANCH	COMMON TRUNK	BIFURCATION	OTHERS	OTHER LEVELS
1	LEFT	+	-	-	+	-	+	-	+	-	-
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3	RIGHT	+	-	-	-	+	+	-	+	-	-
4	LEFT	+	-	-	+	-	+	-	+	-	-
5	RIGHT	+	-	-	+	-	+	-	+	-	-
6	LEFT	+	-	-	+	-	+	-	+	-	-
7	RIGHT	+	-	-	+	-	+	-	+	-	-
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28	LEFT	+	-	-	+	-	+	-	+	-	-
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MASTER CHART																
		ORIGIN OF ECA		RELATION OF ECA WITH ICA		ORIGIN OF STA				ORIGIN OF APA			ORIGIN OF LA			
						SEPARATE BRANCH				SEPARATE BRANCH			SEPARATE BRANCH		COMMON TRUNK	
SP. NO	SIDE	UPPER BORDER OF THYROID CARTILAGE	ABOVE LEVEL OF THYROID CARTILAGE	ANTERO-MEDIAL	LATERAL	FROM ECA above CB	FROM ECA at CB	FROM CCA	TL TRUNK	FROM ECA	FROM CB	COMMON TRUNK	AT GREATER CORNU LEVEL	BELOW GREATER CORNU LEVEL	LINGUO-FACIAL TRUNK	TL TRUNK
31	RIGHT	+	-	+	-	-	+	-	-	+	-	-	+	-	-	-
32	LEFT	+	-	+	-	-	+	-	-	+	-	-	+	-	-	-
33	RIGHT	+	-	+	-	-	-	-	+	+	-	-	-	-	-	+
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35	RIGHT	+	-	+	-	-	+	-	-	+	-	-	-	+	-	-
36	LEFT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
37	RIGHT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
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46	RIGHT	+	-	+	-	-	+	-	-	+	-	-	+	-	-	-
47	RIGHT	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-
48	LEFT	+	-	+	-	+	-	-	-	+	-	-	-	-	+	-
49	LEFT	+	-	+	-	+	-	-	-	+	-	-	-	+	-	-
50	RIGHT	+	-	+	-	+	-	-	-	+	-	-	-	-	+	-

MASTER CHART											
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									AT NECK OF MANDIBLE		
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31	RIGHT	+	-	-	+	-	+	-	+	-	-
32	LEFT	+	-	-	+	-	+	-	+	-	-
33	RIGHT	+	-	-	+	-	+	-	+	-	-
34	LEFT	+	-	-	+	-	+	-	+	-	-
35	RIGHT	+	-	-	+	-	+	-	+	-	-
36	LEFT	+	-	-	+	-	+	-	+	-	-
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46	RIGHT	+	-	-	+	-	+	-	+	-	-
47	RIGHT	+	-	-	+	-	+	-	+	-	-
48	LEFT	-	-	+	+	-	+	-	+	-	-
49	LEFT	+	-	-	+	-	+	-	+	-	-
50	RIGHT	-	-	+	+	-	+	-	+	-	-

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ETHICS COMMITTEE CERTIFICATE

Name of the Candidate	:	Dr.G.B.Lakshmi gayathri
Course	:	PG in MD., Anatomy
Period of Study	:	2015 - 2018
College	:	MADURAI MEDICAL COLLEGE
Research Topic	:	Human Cadaveric study on the branching pattern of External carotid artery
Ethical Committee as on	:	24.12.2016

The Ethics Committee, Madurai Medical College has decided to inform that your Research proposal is accepted.

Member Secretary Chairman Dean / Convenor

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3._Chapter_-II_REview_of_Literature.docx (D29550335)
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This is to certify that this dissertation work titled **HUMAN CADAVERIC STUDY ON THE BRANCHING PATTERN OF EXTERNAL CAROTID ARTERY** of the candidate **Dr.G.B.LAKSHMI GAYATHRI** with registration Number **201533101** for the award of **M.D.,** in the branch of **ANATOMY**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **4** percentage of plagiarism in the dissertation.

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